DOCTOR OF PHILOSOPHY

Evaluating the use of evidence-informed learning strategies for improving secondary school students learning in science

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Award date:
2023

Awarding institution:
Bangor University

PRIFYSGOL
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Prifysgol Bangor

Bangor University

Evaluating the use of evidence-informed learning strategies for improving secondary school students learning in science

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Thesis submitted to the School of Human and Behavioural Sciences, Bangor University, in partial fulfilment for the degree of Doctor of Philosophy

January 2023

Declaration

‘Yr wyf drwy hyn yn datgan mai canlyniad fy ymchwil fy hun yw’r thesis hwn, ac eithrio lle nodir yn wahanol. Caiff ffynonellau eraill eu cydnabod gan droednodiadau yn rhoi cyfeiriadau eglur. Nid yw sylwedd y gwaith hwn wedi cael ei dderbyn o’r blaen ar gyfer unrhyw radd, ac nid yw’n cael ei gyflwyno ar yr un pryd mewn ymgeisiaeth am unrhyw radd oni bai ei fod, fel y cytunwyd gan y Brifysgol, am gymwysterau deuol cymeradwy.

Rwy'n cadarnhau fy mod yn cyflwyno'r gwaith hwn gyda chytundeb fy Ngoruchwyliwr (Goruchwylwyr)

‘I hereby declare that this thesis is the results of my own investigations, except where otherwise stated. All other sources are acknowledged by bibliographic references. This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree unless, as agreed by the University, for approved dual awards.

I confirm that I am submitting this work with the agreement of my Supervisor(s).’

Funding

This PhD was commissioned by the Regional School Improvement Service for North Wales (GwE) in collaboration with the Collaborative Institute for Education Research, Evidence and Impact (CIEREI) in the Schools of Human and Behavioural Sciences and Education at Bangor University.

Acknowledgements

I am grateful to Allah (God) who blessed me with this PhD without Whose guidance, help, mercy and blessings this work would not have been possible. I pray to Allah that I can now use this work to help others.

"And he who has not thanked people has not thanked Allah". Prophet Muhammad (peace be upon him).

Words cannot express my gratitude to my supervisors Professor Carl Hughes and Dr Richard Watkins. I feel especially fortunate to have had the opportunity to complete this PhD under both of your supervision, I could not have wished for better supervisors. Thank you for seeing potential in me right from the beginning. I cannot thank you both enough for all the, encouragement, patience, kindness and unwavering support you have provided throughout the PhD and to this day. I have learnt so so much from you both which has allowed me to develop both personally and professionally. Thank you for believing in me and supporting me with every step since the first day we met in the Brigantia office. You have both always provided me with invaluable feedback on the work, I have learnt so much from you and really enjoyed learning from you and I look forward to learning more from you. I have truly enjoyed working with you both on this PhD. I look forward to continuing working with you both.

This work would not have been possible without the Regional School Improvement Service in North Wales (GwE), who commissioned the PhD. A very special thanks to the GwE advisors, teachers and learners across schools in Wales for their invaluable contribution to the thesis studies.

I am also grateful to Dr Tarek Al Baghal who generously provided knowledge, help and expertise on survey research methods for the PhD. Additionally, Professor Martina Feilzer and Professor Peter Lynn for their time, knowledge and advice with the thesis survey design and Dr Zoe Hoare for her kind advice and knowledge on RCTs.

Lastly, I would like to thank my family and friends. My parents and siblings, a very special thank you for your unwavering belief that I can accomplish this PhD and for always supporting me and for never asking me when or how much longer it would take to complete the PhD. My brothers Yunus, Yaqub and Ibrahim - thank you for the quality time we spend together. Bethan, thank you for always being there whenever I needed to talk, for your kindness and friendship. My school teachers who believed in me when I didn't know what it meant for others to believe in you. I hope I can inspire others like too.

A special thank you to everyone else who I have met during the course of this PhD journey who have helped in some way or another.

This PhD has been one of the biggest learning opportunities I have been blessed with.

Thesis abstract

The effective teaching of science is vital for prosperity, economic growth as well as for the public understanding of important contemporary issues such as climate change. The outcomes students achieve in school science can play an important role in their future career paths. In Wales, science standards as well as the uptake of science subjects by students has been an area of concern and debate for some time. The performance of Welsh learners in the most recent Programme for International Students Assessment rankings from 2018 remained lower than the OECD average when Wales first participated in PISA tests in 2006 and Wales's science scores have remained below the other nations of the UK. Additionally, in Wales the uptake of science subjects by students has been an area of concern and debate for some time. The learning strategies students use can have an impact on the outcomes they achieve. Through effective learning strategies students study skills can be improved. Research shows that using effective learning strategies has positive effects on academic performance essential for lifelong success. The aim of the thesis was to evaluate the use of evidence-informed learning strategies to help improve secondary students' science performance.

This thesis comprises five chapters. The first part of Chapter 1 explores students' science performance in Wales, the existing literature on evidence informed learning strategies - including definitions, utility categories, use and understanding of learning strategies by student populations - and the limitations in the research methods used in existing studies. There is a very limited range of research that uses robust survey methods. In the second part of Chapter 1 we discuss survey research methods in education and present our own survey work development for the studies presented in later chapters. Importantly this section outlines the steps required to use probability sampling methods for selecting a random sample.

Chapter 2 presents a survey study with science subject leaders teaching in secondary schools in North Wales that evaluated their understanding of learning strategies and how they communicate this to learners. Chapter 3 reports on two survey studies with secondary age learners. Study 1 is a population based-survey that investigated the use, and understanding of, evidence-informed learning strategies among secondary school students from a total of 29 secondary schools in North Wales. The second study is a survey evaluating the influence of the COVID-19 pandemic on secondary age students' independent learning practice that was commissioned by the Welsh Government. Chapter 4 describes the development of a programme designed to help students preparing for examinations in science. The Improving Standards through Effective Revision (iStER) programme aimed to teach school students about the most effective learning strategies that enhance learning and show potential to improve academic performance. In addition, Chapter 4 presents a single blind parallel feasibility randomised control efficacy trial of a lunchtime study and revision programme for learning GCSE Chemistry using the iStER programme in a secondary school in North Wales and lessons learned for a future definitive RCT. The final chapter, Chapter 5, provides a summary of the thesis research findings and discusses their implications, strengths, limitations and suggestions for future research in this area.

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Glossary

Acronym/Key term	Definition
CEN	Collaborative Evidence Network
AoLE	Areas of Learning and Experience
CIEREI	Collaborative Institute for Education Research, Evidence and Impact
CPD	Continuous Professional Development
cRCT	Cluster Randomised Controlled Trial
CSC	Central South Consortium (Regional Education Consortium)
EAS	Education Achievement Service (Regional Education Consortium)
GCSE	General Certificate in Secondary Education
GwE	North Wales School Effectiveness and Improvement Service
iStER	Improving Standards through Effective Revision
PGCE	Post Graduate Certificate in Education
Pioneer Schools	Pioneer Schools refer to a group of schools identified to work collaboratively to co-construct key aspects of the Curriculum for Wales.
RCT	Randomised Controlled Trial
WJEC	Welsh Joint Education Committee.

Thesis summary

This thesis contains five chapters.

Chapter 1. The first section of Chapter 1 provides contextual information on the focus of the thesis, including the background to the work, a review of the existing literature and the overall aims of the thesis including definitions of key terminology. The second section explains the rationale for the research methods we employed for the empirical studies included in this thesis. This section also describes the preliminary survey work that was conducted that informed the use of more robust survey designs and led to the studies outlined in the studies in this thesis.

Chapter 2 describes a survey study with science subject leaders teaching in secondary schools in North Wales. The aim of this study was to first evaluate the range of learning strategies schools promote to help students learn science. At the start of this study there was no published research with educators in secondary schools evaluating their recommendations of evidence-informed learning strategies. We conducted a cross-sectional survey using paper-based questionnaires with thirty-five science subject leaders attending a biannual heads of science forum meeting in October 2018. Our findings showed that teachers encourage the use of both high and lower utility strategies with school students, and that they have a moderate understanding of the utility of effective strategies. The findings highlight the need for all teachers, both trainee, newly qualified and more experienced, to gain a greater understanding of evidence-informed learning strategies.

Chapter 3 presents two studies. Study 1 is a population-based survey of secondary school students' use and understanding of learning strategies and their independent learning practice for science examinations. For this survey, we employed a random probability sampling method for a sample selection (i.e., multistage implicitly stratified sampling). Our results showed that the learning strategies most frequently used by secondary students were making notes, repeatedly reading information, and highlighting [or underlining] information (i.e., less effective learning strategies). More effective learning strategies were less frequently used by students (i.e., retrieval and spaced practice). In addition, we found that students do not generally have an accurate understanding of the effectiveness of the learning strategies they frequently use. The results also highlighted the need to improve awareness about the relative utility of learning strategies used by students, including the provision of improved guidance on the use of more effective learning strategies. We have used these findings, along with

other research in cognitive and educational psychology to develop a learning resource called Improving Standards through Effective Revision (iStER) programme to educate school students about the most effective learning strategies.

Study 2 is a survey evaluating the influence of the COVID-19 pandemic on secondary aged students' independent learning practice that was commissioned by the Welsh Government (the full draft report is presented in Appendix E). During the COVID-19 pandemic school closures, most students were required to complete schoolwork at home. Given the need for students to work independently, we wanted to evaluate whether students' independent learning practice might have changed. We conducted an online cross-sectional survey with students aged 14–15 and 16–17 years old attending secondary schools in Wales. For this survey, we employed a multistage clustered sample design for a sample selection. The findings were similar to our previous survey research with secondary students outlined in Study 1 of Chapter 3 and showed that students reported using both less and more effective learning strategies whilst learning at home. The data also suggest that students do not have an accurate understanding about the effectiveness of some common learning strategies. This was despite the need for students to work more independently. Importantly, these findings suggest that students' use and understanding of learning strategies have not changed significantly since the start of the pandemic and highlights the need for schools to continue to improve awareness about effective learning strategies and resources in Wales.

Chapter 4 provides a detailed description of the iStER learning resource developed during the course of this work, as well as a single blind parallel feasibility randomised controlled efficacy trial of lunchtime study/revision sessions for using the iStER programme to help secondary students learn (study/revise) GCSE Chemistry. The primary aim of the feasibility efficacy trial was to assess the feasibility of conducting a future definitive RCT. Our primary objectives in this phase were to test the feasibility (recruitment and retention rates, completion rates, attendance, adherence to intervention) of undertaking an experimental study to evaluate the impact of using the iStER programme during lunchtime study/revision sessions to learn GCSE chemistry content. After completing training and pre-tests, we had to stop the trial earlier than planned in March 2020 due to school closures caused by the COVID-19 pandemic.

Chapter 5 provides an overall discussion of the main themes derived from the studies in this thesis. This includes a discussion of the overall findings, the implications and applications, strengths, and limitations of the empirical research studies. The methodological challenges experienced during the course of this work are discussed, including suggestions for future work and the next steps for the iStER learning programme. The chapter concludes by providing a reflection on the PhD thesis and future aims.

Chapter 1: Introduction

Preface

Our broad aim in this doctoral thesis was to evaluate the use of evidence-informed learning strategies to help improve the science performance of secondary school students in North Wales. In 2013, Dunlosky et al. evaluated ten commonly used learning strategies by student populations and provided a useful utility ranking of the learning strategies. The findings have important implications for teaching and particularly for students' independent learning practice to improve outcomes they achieve. Globally, research into secondary students' independent learning practice is limited. In the UK, there is currently an absence of empirical research from secondary schools that evaluates students' study/revision practice for GCSE qualifications, including the learning strategies evaluated by Dunlosky et al. (2013).

In the first part of this chapter, we provide contextual information on student science performance in Wales, the importance of science study in schools, and present a review of the literature on evidence-informed learning strategies and more broadly on students' independent learning practice. We also outline the current gap in our understanding of learners' independent learning practice as well as the limitations in the research methods used in existing studies. In the second part of this chapter, we discuss survey research methods in education and present our own survey work development for Chapters 2 and 3. In addition, we give some context on the research methods we employed for the feasibility trial we conducted in Chapter 4.

Students' science performance

Figures from the previous round of Programme for International Student Assessments undertaken in 2018 showed that the science achievement scores of 15 year old secondary students in Wales slightly improved for the first time since a series of disappointing figures were observed from 2009 to 2015 (Organisation for Economic Co-operation and

Development [OECD], 2010; OECD, 2014a; Sizmur, Ager, Bradshaw, Classick, Galvis, Packer, Thomas & Wheater, 2019). Students' science scores in Wales remained lower than the OECD average when Wales first participated in PISA tests in 2006, and Wales's science scores have remained below the other nations of the UK in the most recent PISA rankings from 2018 (OECD, 2007; Wightwick, 2019). However, in a recent review of the sampling strategies used for the PISA assessments, Jerrim (2021) suggested that students' science scores in Wales should be lower than the scores that were reported in the 2018 assessments as due to methodological errors (i.e., survey non-response bias at the student level). Additional thematic reports on the state of science in Welsh schools by the education inspectorate, Estyn, highlighted the need to improve secondary school students' science performance (Estyn, 2017).

In Wales, science standards as well as the uptake of science subjects by students has been an area of concern and debate for some time (Wightwick, 2017a; Wightwick, 2017b). In 2017, the Minister for Education launched a £4m scheme to raise students' standards in science and technology in Wales. There have been many other projects partly funded by Welsh Government to inspire students to study science subjects in further and higher education and to encourage young students into high skilled science, technology, engineering and maths (STEM) careers (e.g., Trio Sci Cymru, Swansea University Science for Schools Initiative, The Welsh Valleys Engineering Project). In North Wales, the Welsh Government's STEM Gogledd programme was launched with the same aims to inspire and encourage students.

Importance of Science

Science forms a key part of the school curriculum across the UK and internationally. In the UK science has been a core subject of the school curriculum since 1989. The effective teaching of science is vital for prosperity, economic growth as well as for the public understanding of important contemporary issues such as climate change. As outlined by the OECD (2014b; 2017; 2020), a solid grounding in school science is an important prerequisite to enable students to engage with many of the challenging issues facing contemporary society.

In their report on the standards, provision and leadership in science at Key Stage 3 and Key Stage 4 in Wales, Estyn recommended that the Welsh Government should attract more science graduates to teaching (Estyn, 2017). In addition, two recommendations were made for local authorities and regional education consortia on science at Key Stage 2 and Key Stage 2 (Estyn, 2017). First, it was recommended that tier two organisations should provide more subject specific support for science on improving teaching and assessment, and facilitate the sharing of good practice. Secondly, it was recommended that tier two organisations (such as local authorities and regional consortia) should provide more support for schools to evaluate their curricula, and plan for the development of Science and Technology Area of Learning Experience (AoLE), as well as the changes to qualifications in science. In response, the Welsh Government began working in conjunction with Pioneer Schools, regional consortia and Estyn to develop the Science and Technology Area of Learning Experience and tasked the National Network for Excellence in Science and Technology (Welsh Government, 2017). Given the complexity and uniqueness of student learning experiences, policy responses to help improve students' standards in science require a variety of evidence-informed strategies and approaches. The use of evidence-informed learning strategies for independent learning (i.e., study and revision) can play an important role in helping students in secondary schools improve standards in science and prepare for external science examinations.

In 2018 regional education consortia in North Wales Regional School Improvement Service (GwE) commissioned a collaborative PhD project with the Collaborative Institute for

Education Research, Evidence and Impact (CIEREI) in the Schools of Human and Behavioural Sciences and Education at Bangor University. The aim of this PhD is to investigate the use of evidence-informed learning strategies to help secondary students improve standards in science.

This PhD research is focused on the importance of school science, in particular the General Certificate of Secondary Education (GCSE) qualification in science. Our aim in this PhD was to help secondary school students aged 14–15 years (in school Year 10) to improve their school science performance using evidence-informed learning strategies. Another reason why we chose to focus on school science was because this was a focus for enquiry alongside our partners in the North Wales Regional School Improvement Service.

Importance of GCSE science

Students in Wales begin studying towards the General Certificate in Secondary Education (GCSE) in Year 10. GCSEs are generally two-year programmes offering a range of subjects, including compulsory subjects such as science, English, mathematics, and optional subjects such as geography, history, design and technology. At the end of each programme of study, students undertake an examination to assess their knowledge and understanding on the science content. Importantly, the GCSE qualifications students achieve can play an important role in their future academic and career paths, and are highly valued by schools, colleges and universities and employers. We focused on students in Year 10 as that was also a focus for enquiry alongside our research partners in the North Wales Regional School Improvement Service.

Learning strategies

The use of evidence-informed learning strategies for independent learning (i.e., study and revision) can play an important role in helping learners in secondary schools prepare for external examinations. Learning strategies can be described as the methods students use to promote learning and understanding of key content and ideas on their own, usually in preparation for low stakes and/or high stakes summative assessments. Oakes and Griffin (2016) describe learning strategies as the activities students undertake for their independent work – that is, *how* they go about learning key content and ideas on their own outside of the classroom without help from teachers, to understand and recall content. Research has shown that students' use a variety of learning strategies to help them study in preparation for examinations (Dirkx et al., 2019; Karpicke, Butler & Roediger, 2009). Examples of some commonly used learning strategies by student populations include repeated reading approaches, summarising (making notes), completing retrieval practice activities and highlighting or underlining information (Dirkx et al., 2019; Karpicke, Butler & Roediger, 2009).

Although research has documented on students' use of learning strategies, it is important to understand whether these are indeed effective ways to learn (i.e., does the use of these strategies improve academic performance?). Several studies have shown that using retrieval practice is related to higher exam scores, whilst highlighting information is related to lower exam scores (Bartozewski & Gurung, 2015; Gurung, Weidert & Jeske, 2010; Hartwig & Dunlosky, 2011; Rodriques, Rivas, Matsumura, Warschauer & Sato, 2018). Moreover, we now know from an important comprehensive review of the research evidence on learning strategies by Dunlosky et al. (2013) which learning strategies are rated as high-, moderate-, and low utility. Dunlosky et al. (2013) arranged the ten commonly used learning strategies based on how effective the strategies generalise across a range of key variables (e.g., learning conditions, student characteristics, materials and criterion tasks). Of the ten learning strategies evaluated two strategies were identified as high utility (practice testing [note that we use the term retrieval practice in this thesis] and distributed practice [note that we use the term spaced practice in this thesis]), three strategies were identified as having moderate utility (interleaved practice, elaborative interrogation, and self-explanation), and five strategies were identified as having low utility (summarising, highlighting [or underlining], using keyword mnemonics, imagery use for text learning and repeatedly reading information). These findings have important implications for learning and teaching and for students' independent learning practice.

Thesis aims and objectives

The main aim of this thesis is to evaluate the use of evidence-informed learning strategies to help improve secondary students' science performance. This thesis will examine the way in which we can promote the use of evidence-informed learning strategies to help improve secondary students' independent learning practice in preparation for GCSE science examinations. The purpose of our survey studies was a scoping exercise and to collate evidence that would help inform our next steps in the PhD in terms of developing guidance for secondary students on evidence-informed learning strategies, such as a learning programme for students in secondary school settings to help students with independent learning. The specific objectives for the empirical studies in this thesis were as follows:

1. To undertake a survey evaluating science subject leaders' understanding and recommendations of evidence-informed learning strategies to help students revise for science.
2. To undertake a population-based survey evaluating secondary students' use and understanding of study and revision strategies for science examinations.
3. To undertake a feasibility randomised controlled trial of a lunchtime study/revision session to learn GCSE chemistry using the iStER programme.

In this research, we focused on the evaluation of six of the learning strategies described by Dunlosky et al. (2013) as well as three other commonly used learning strategies identified in the literature on students' study practice. Table 1.1 presents the learning strategies included in this study and their relationship with other terms used in the research literature.

Table 1. 1 *Overview of commonly used learning strategies evaluated in the current thesis*[a]

Learning strategy		
Terms used in present study	Terms used by Dunlosky et al. (2013)	Description
Highlighting or underlining information	Highlighting/underlining	To mark out important content (i.e., key words, text) of the to be learned material with a bright/different colour while reading
Repeatedly reading information	Rereading	Reading information over and over
Making notes (summarising)	Summarisation	Writing notes/summaries (of various lengths) of the information to be learned
Spaced practice	Distributed practice	Implementing a schedule of study/revision practice where study time is separated into multiple sessions overtime. Reviewing learning materials studied earlier in later sessions.
Doing practice tests	Practice testing	(i.e., retrieval practice) Retrieving information from memory in absence of the information to be remembered by using practice tests, past papers, quizzes, flashcards (or any other

Learning strategy		
Terms used in present study	Terms used by Dunlosky et al. (2013)	Description
		activity which involves actively retrieving information from memory
Interleaved practice	Interleaved practice	Mixing study of different, related topics, concepts or problems. Implementing a schedule of study practice that mixes different kind of skills, subjects or topics within a single study session
Elaborate encoding[b]		Connecting what you are trying to learn to what you already know (e.g., using mnemonics). Making connections between information to be learned and other information.
Using mind maps[c]		Writing down a key topic, and from this creating links composed of keywords, phrases, concepts, facts and figures. Mind maps are typically presented as diagrams.
Using flashcards[d]		Writing key terms, facts or to be learned information on small cards. Flashcards are typically two-sided with the prompt / question appearing on one side and the information about the prompt / answer on the other).

Note. [a]This thesis assessed the use of six strategies evaluated by Dunlosky et al. (2013). In the present thesis, three additional learning strategies identified in the literature on student study habits were also included (*elaborate encoding*, *using flashcards* and *using mind maps*).
[b,c,d]Neither of these strategies were recognised in the review by Dunlosky et al. (2013).
[d]Using flashcards and doing practice tests can be used as retrieval practice activities. However, in the present study, we analysed using flashcards and doing practice tests separately.

There is some variability between the definitions and terms of the learning strategies evaluated in the current thesis studies and in Dunlosky et al.'s (2013) review. In particular, there is some variability between the terms used in Dunlosky et al. 's (2013) review and the Effective Revision and Study Strategies Questionnaire (ERaSSQ) we developed to measure students' use of learning strategies (Chapters 3 and 4). In the following section we highlight some of these differences and explain the reasons for the amended definitions of three of the learning strategies evaluated in the current thesis compared to those used in Dunlosky et al. (2013). The three strategies are presented below:

1. Making notes (summarising). Dunlosky et al. (2013) used the term summarisation, and in this thesis we preferred the term 'making notes (summarising)'. We used the term 'making notes' because students in the schools we worked with were more familiar with this term as opposed to the term summarising. Also, summaries can be of various lengths (i.e., can consist of single words, sentences, or longer paragraphs). As earlier researchers have pointed out, 'summarisation' is not one strategy but a family of strategies' (Pressley, Johnson, Synnons, McGoldrick & Kurita, 1989, p.5). Moreover, in similar studies with secondary and university students evaluating the use of learning strategies among student populations, there is some variability between the definitions used for summarisation by those authors and in Dunlosky et al.'s review (2013) (Biwer et al., 2020; Dirkx et al., 2019). In the study by Dirkx et al. (2019) with secondary students, one of the examples used for the learning strategy, summarising, from students' responses to the open-ended questions was *write down important information,* which we consider to represent the noting down of information and ideas (i.e., making notes). In a more recent study by Biwer et al. (2020) with university students, the authors defined summarising as, writing down main points from a text.

2. Spaced practice is the term used in this study in preference to the term distributed practice used by Dunlosky et al. (2013). The term spaced practice is also widely used in the literature.
3. In our study with students presented within Chapters 3 and 4 we used the term *doing practice tests* to refer to retrieval practice in the ERaSSQ survey. Dunlosky et al. (2013) used the term practice testing. However, throughout this thesis we use the term retrieval practice to refer to the terms *doing practice tests* and practice testing. This is because there are many ways in which this strategy can be applied, it was therefore important to use a term which captures all such retrieval practice activities.

In this thesis we also evaluated students' use and understanding of three additional learning strategies identified in the literature on students' study practice (Blasiman et al., 2017; Debbag et al., 2021; Garwood et al., 2018; Hartwig & Dunlosky, 2012; Morehead et al., 2016; Safar et al., 2014; Oakes & Griffin, 2016; Ying et al., 2017). These strategies were using flashcards, using mind maps and elaborate encoding. Using flashcards and mind maps are more versatile strategies in terms of how they can be applied by students. For this reason, we have provided some additional information on these strategies below:

4. Using flashcards. Flashcards are a versatile study stool and can be used in more than one way. Flashcards can be used as a retrieval practice activity (e.g., students can read a question, and then practise recall of the answer), as a repeated reading approach (e.g., students can write down information, facts and then repeatedly read over the information) or as study tools for making notes (e.g., students can write notes on a flashcard).
5. Using mind maps is a common learning strategy used by students in the schools we worked with and in schools in the UK (Safar et al., 2014; Oakes & Griffin, 2016). This is a more versatile learning strategy in terms of *how* it can be used. Mind maps

can be used as an effective method to take notes, as a repeated reading approach (students can write down information, facts and then repeatedly read over the information).

Evidence-informed learning strategies

In the following section we provide additional information on the two most effective strategies (i.e., retrieval and spaced practice), which were the focus of the current PhD studies and the iStER learning programme we developed to help students with independent learning (presented within chapter 4). As discussed earlier on, the utility ratings for the learning strategies are from Dunloskty et al. (2013).

Retrieval practice

Retrieval practice is a learning strategy based on retrieving information from memory (i.e., practising recall) in absence of the information to be learned. The process of retrieval (i.e., recalling information to mind) strengthens the memory for that information, leading to enhanced long-term learning and improved recall of the information that was retrieved (Bjork & Bjork, 2011; Roediger & Karpicke, 2006). Examples of retrieval practice activities include completing quizzes, class tests, past papers exam questions, using flashcards, writing notes from memory.

In an important study on retrieval practice, Roediger and Karpicke (2006), investigated the effects of retrieval practice versus restudying material with university students. In two experiments, students read prose passages and either repeatedly read the passage or used retrieval practice to learn the information. Findings from both experiments showed that after a five-minute delay, students' performed better on the free recall tests after initially repeatedly reading the text. However, after longer delays (i.e., 2 days, or 1 week later) students' performance was greater when they engaged in initial retrieval practice. Their findings indicated that retrieval practice has a powerful effect on long-term retention and suggest that using retrieval practice for study promotes better long-term learning. Importantly, Roediger and Karpicke's (2006) study led to a resurgence of interest in the testing effect, with researchers exploring the use of retrieval practice as a learning strategy in applied educational settings for improving educational practice.

Retrieval practice is also referred to as the 'testing effect'. This describes the finding that being tested on information can result in better recall of the information. The key feature in all retrieval activities is that information is actively recalled from memory and not passively re-read. Researchers have used other terms to refer to retrieval practice including self-testing, practice testing (Dunlosky et al., 2013). One reason why researchers might have used different terms is because retrieval practice is a learning strategy which can be applied in more than one way (i.e., due to the varying forms of retrieval practice activities that exist).

More recent reviews of the evidence (i.e., systematic and meta-analytic reviews) on retrieval practice have showed that retrieval practice improves student learning outcomes in university and school settings with educational material and can reduce test anxiety in secondary school students (Agarwal, Nunes, Blunt, 2021; Agarwal, D'Antonio, Roediger, McDermott & McDaniel, 2014; Sotola & Crede, 2021; Yang et al., 2021).

In education settings, the use of retrieval practice is already an established method used as part of general classroom instructions. For example, tests and quizzes are different forms of retrieval practice activities and are frequently used by educators to assess student learning for formative and/or summative purposes. However, in this form educators have traditionally used retrieval practice for assessing student learning for summative or diagnostics purposes rather than as a learning strategy.

In this thesis, we aim to first assess the use and understanding of this effective learning strategy among teachers and students in secondary school settings. Information on teachers' and students' use and understanding of learning strategies for independent learning can provide insight and understanding on how teachers promote this effective learning strategy, and how students use effective strategies. In addition, this will provide valuable evidence to inform guidance on how to best promote effective learning strategies in schools as part of the next phase of this research. It will also provide valuable evidence to inform our school improvement partners advice to schools on the most effective learning strategies.

Spaced practice

Spaced practice is a learning strategy based on *when* students should practise recalling knowledge and/or ideas. It involves spacing out study sessions over time and reviewing previously learnt information in successive sessions. This can help to slow down the rate of forgetting newly learned information leading to enhanced learning. This learning strategy is underpinned by the forgetting curve and has been shown to be effective for learning by subsequent research on the spacing effect (Ebbinghaus, 1885/2006; Bahrick et al., 1993). In this thesis we aim to first assess the use and understanding of this effective learning strategy among teachers and students in secondary school settings.

There is now an accepted consensus in the research literature that retrieval and spaced practice are effective, higher utility learning strategies that can help students learn new material (Dunlosky et al. 2013; Yang et al., 2021). In addition, various books and teacher resource guides, plus a growing number of web-based and smartphone programmes that focus on the use of spaced practice and retrieval strategies in schools (e.g., CogSciSci [https://cogscisci.wordpress.com/]; Research Schools Network [https://researchschool.org.uk/news/effective-retrieval-practice-what-should-we-consider]; Seneca [https://senecalearning.com/en-GB/]). The aim of this collaborative PhD research was to improve the quality of students' independent learning skills in preparation for GCSE science examinations. Before providing guidance on evidence-informed learning strategies and developing new learning resources for students, an important first step was to review the existing research on students' use of learning strategies. In the following paragraphs we outline the literature, including the research on what learning strategies are promoted in educational settings.

Recommendation of learning strategies from educators

The use of evidence-informed learning strategies has become an important subject both in teacher continuing professional development (CPD) circles and also researcher-driven websites and fora aimed at getting evidence into education (e.g., The Learning Scientists [https://www.learningscientists.org/], Unleash the Science of Learning [https://www.retrievalpractice.org/], Bringing cognitive science to the science classroom [https://cogscisci.wordpress.com/], Ferlazzo, 2021). School teachers are an important source of information and guidance for students as they prepare to learn and revise for examinations. To increase the use of evidence-informed learning strategies in schools, it is important to understand what learning strategies teachers are promoting and what they understand about effective learning strategies. Studies showed that university instructors promote both less and more effective learning strategies and have a moderate understanding about evidence-informed learning strategies (McCabe, 2018; Piza, 2018; Morehead et al., 2016). Previous published research on instructors' recommendations and understanding of learning strategies is limited to surveys of higher education instructors and there remains a paucity of research evaluating the strategies teachers most commonly promote in schools (McCabe, 2018; Piza, 2018; Morehead et al., 2016).

Recently, Surma et al. (2022) conducted a survey with newly qualified secondary teachers in Belgium on their recommendations and understanding of effective learning strategies such as retrieval and spaced practice. The findings of Surma et al. (2022) showed that secondary these teachers understood the effectiveness of higher utility learning strategies such as retrieval and spaced practice. However, Surma et al. (2022) also found that these higher utility strategies were recommended less frequently by the teachers, compared with lower utility strategies such as summarising. There is currently no research in the UK that has evaluated the learning strategies promoted by teachers in secondary schools. It is important to know which learning strategies are currently being promoted by teachers in secondary schools and also students' use, and understanding of, these strategies. The aim of this thesis is to close this knowledge gap. Within Chapter 2 we outline a cross-sectional survey we conducted with science subject leaders in North Wales. Our survey with science teachers aimed to evaluate the learning strategies science subject leaders promote in schools to help students revise in preparation for science examinations. Importantly, this information will help our project partners provide additional guidance to schools to help students access and use more effective learning strategies.

Students' use and understanding of learning strategies

Despite the need for learners to rely on learning strategies for their independent learning activities, and the growing body of literature highlighting evidence-informed learning strategies, there are currently only two published studies that have attempted to investigate the use of learning strategies by secondary aged students in mainstream school settings (Agarwal et al., 2014; Dirkx et al., 2019). Most of the earlier research on the use of learning strategies is limited to surveys of undergraduate students across a variety of disciplines including the social sciences, medicine, pharmacy and dentistry (Bartozewski & Gurung, 2015; Biwer, Egbrink, Aalten & de Bruin, 2020; Blasiman, Dunlosky & Rawson, 2017; Gurung et al., 2010; Hartwig & Dunlosky, 2011; Karpicke et al., 2009; Kornell & Bjork, 2007; McAndrew, Kamboj & Pierre, 2015; McAndrew, Morrow, Atiyeh & Pierre, 2016; Peña, Knecht & Gavaza, 2021; Piza, 2018; Rodriguez et al., 2018; Schmidmaier et al., 2011; Susser & McCabe, 2013; Morehead, Rhodes & DeLozier, 2016).

In 2014, Agarwal et al. conducted the first survey with secondary school students in the United States and found that these students relied on less optimal learning strategies (i.e., repeated reading approaches), compared to more effective ones such as retrieval practice. Agarwal et al. 's (2014) study also showed that secondary students reported using retrieval practice (i.e., an effective learning strategy) as a diagnostic tool to evaluate their learning, rather than as a method to actually *learn* information. This was despite students' participating in a classroom-based retrieval practice intervention where learners completed retrieval practice activities for the duration of one academic year (i.e., clicker quizzes). Although Agarwal et al.'s (2014) study was the first to explore the use of learning strategies by secondary school students, the survey responses were based upon data collected from students at the end of an experimental study on retrieval practice (i.e., an effective learning strategy), and this may have influenced students' responses.

A more recent survey with secondary school aged learners was undertaken with students in the Netherlands and revealed that these school students similarly relied on less optimal learning strategies (i.e., repeated reading approaches and making notes) for independent learning (Dirkx et al., 2019). Interestingly, Dirkx et al. 's (2019) study also found school students did not rely on highlighting information (i.e., a less effective learning strategy). This finding contrasted with earlier studies with university students which consistently showed students highlighted information as a learning strategy. Previous research in school settings outside the UK has established that secondary age students rarely make use of the most effective learning strategies (Agarwal et al., 2014; Dirkx et al., 2019). There is currently no research on the use of learning strategies in schools in Wales, and research into this field in the UK more widely is underdeveloped.

There has been some school based enquiry work carried out by Oakes and Griffin (2016) on the study practice of school aged students in the UK. In a book by Oakes and

Griffin (2016) the authors briefly report findings from a survey undertaken in schools with students following Advanced Level courses (aged 16 to 17 years). Oakes and Griffin's findings showed these students similarly relied on less optimal learning strategies (i.e., reading approaches and highlighting information) for their independent learning.

In addition, no single study exists that has explored secondary students' understanding of learning strategies. If we are to make recommendations of evidence-informed strategies or develop interventions using evidence-informed strategies for learners, it is equally important to investigate students' understanding of learning strategies. This information will help us to understand the potential barriers to students' using more effective learning strategies (i.e., lack of awareness about more effective learning strategies, insufficient knowledge about the efficacy of the learning strategies they commonly use). Studies in university settings have shown that undergraduate students' have limited knowledge of effective learning strategies and they primarily use retrieval practice (i.e., an effective learning strategy) as a diagnostic tool to evaluate their learning, rather than as a method to actually *learn* information (Hartwig & Dunlosky, 2012; Kornell & Bjork, 2007; Kornell & Son, 2009; McAndrew et al., 2016; McCabe, 2011; Morehead et al., 2016; Piza, 2018; Schmidmaier et al., 2011). In a recent survey Blasiman et al. (2017) asked university students to rate the effectiveness of various learning strategies, and findings showed less optimal learning strategies were rated as effective by the highest proportion of students (i.e., reading and highlighting notes). Our aim in this thesis was to close this knowledge gap. Our survey studies with secondary students presented within Chapter 3 focused on both the use and understanding of learning strategies.

Another issue with prior research on secondary and university students' study practice is that previous research has used non-probability sampling methods (i.e., convenience sampling) and, therefore, did not include a random sample of learners. A limitation of this approach is that the results from previous studies are likely to be biased towards over- or under-reporting due to students who were more- or less interested in independent study and in improving their independent study skills and therefore more likely to take part in the survey. In Wales and other countries in the UK, science classes are commonly arranged according to student ability (i.e., more academically able students typically follow triple science award, with the remaining students generally following the double science and BTEC/applied science qualifications). It was important, therefore, to ensure that the sample of students in this study was representative of students of different academic abilities. As part of our literature review on students' use of learning strategies and our preliminary survey work (discussed below), we recognised that the use of non-probability sampling techniques is widespread among survey research within education. In this thesis we elected to use probability sampling methods to improve the quality and generalisability of survey findings.

Independent learning skills and other key aspects of independent study

In addition to educating students about effective learning strategies, students would also benefit from learning about independent learning practice (i.e., what is study, revision) and other key aspects of independent learning such as investing effort (i.e., time) towards independent learning, activities to help students develop the habit of independent practice, as well evidence-informed approaches, study tools to apply effective learning strategies. A combination of these aspects is important for students to incorporate effective learning strategies into their daily practice and become independent life-long learners. Oakes and Griffin (2016) proposed five behaviours and characteristics that all students need to be successful, including vision, effort, system, practice and attitude. These five qualities form the acronym for the VESPA system.

School-based support with independent learning

It is important that schools have an appropriate repository of resources available to help learners use more effective learning strategies for independent learning. We have previously discussed how teachers are an important source of information for learners and previous studies with university students has shown that students more commonly rely on less effective strategies. To increase the use of effective learning strategies, it is important to identify what provision is currently in place for students in schools. There are currently no studies which have evaluated the provisions of study/revision support in schools (i.e., support centres). Our aim in this thesis is to close this knowledge gap (Chapters 2 and 3).

Improving the quality of study designs in education research

Much of the earlier surveys using probability methods has been limited to large-scale international evaluations such as the PISA studies and Trends in International Mathematics and Science Study (TIMSS) (OECD, 2007; OECD, 2010; OECD, 2014; [https://nces.ed.gov/timss/datafiles.asp]. There is a lack of published research describing the use of probability sampling methods for smaller scale surveys in education research which aims to improve the generalisation of findings to wider populations of school students in a specific region (e.g., North Wales). Importantly, the use of more robust survey design methodologies is an important first step towards the generation of more trustworthy education research outputs. Therefore, one of the main aims of this thesis was to use probability sampling methods to obtain more generalisable findings. Importantly, employing such a sampling methodology will provide a useful model for other researchers to consider in education research. There have been some smaller scale population based-surveys with school students that used probability methods undertaken by organisations such as the National Centre for Social Research (NatCen) and the National Foundation for Educational Research (NFER) using survey statisticians (The Information Centre, 2007).

Preliminary survey work

This section aims to provide the rationale for the research methods we employed for the empirical studies included in the thesis chapters 2, 3 and 4. In this section we begin by reporting on our pilot survey work with secondary students which played a key role in the development of our surveys with teachers and students outlined within chapters 2, 3 and 5. We then describe the methodologies we used for our surveys with school students and teachers, and provide the rationale for the survey designs we employed (i.e., sampling method, sample size calculation).

Survey measure development

We developed the Effective Revision and Study Strategies Questionnaire (ERaSSQ) (see Appendix A) to measure secondary students' independent learning practice. There were existing measures for assessing students' use of learning strategies such as the Motivated Strategies for Learning Questionnaire (MLSQ) (Pintrich et al., 1991). However, MLSQ did not include the learning strategies recently evaluated by Dunlosky et al. (2013), nor other commonly used study tools by students (i.e., using flashcards, mind maps), nor questions on students' understanding of learning strategies. We also wanted to measure school-based support for students' study/revision skills and the MLSQ does not cover this aspect. We also wanted to know what learning strategies secondary teachers were promoting to students, and whether there was a demand from students to be provided with more information about evidence-informed learning strategies.

Importantly, collating this information would also help us decide whether there is a need for us to develop additional guidance and resource materials on independent learning skills for educators and learners in secondary schools. Therefore we designed the ERaSSQ to incorporate these additional requirements (e.g., students' use and understanding of these common learning strategies for science, effort towards independent learning and school-based support with study/revision). The survey items on the use and understanding of learning strategies were informed by previous research on students' study practice (Blasiman et al., 2017; Dunlosky et al., 2013; Karpicke et al., 2009; Kornell & Bjork, 2007). Another key aspect of students' study practice identified following a review of the literature was the effort learners make towards independent learning. The survey items on effort towards independent study were informed by Oaks and Griffin's (2016) 1-10 effort scale.

Between June and July 2018, we piloted the ERaSSQ with 535 students (aged 14 to 17 years) attending five secondary schools in North Wales. Although we were able to obtain responses from 535 students, we used a non-probability (or non-random) sampling technique (i.e., convenience sampling) for a sample selection. A limitation of this approach is the survey findings are biased. Given that our aim was to pilot the ERaSSQ survey in the early stage of the PhD, convenience sampling was an appropriate technique for our purpose.

In the following section we describe the survey methodologies we used for our survey studies presented within Chapters 2 and 3. We explain the methodologies we used for our empirical studies in this thesis. We begin with the survey studies presented within Chapters 2 and 3.

Survey research methods in education

Despite the increasing use of evidence within education, there remains a paucity of accessible guidance surrounding sample size-calculation and survey designs for designing school based-surveys. There are many useful guides and textbooks written on survey research methods for clinical research, and sampling and sample size calculations for survey research that can be adapted for school-based surveys (for sample size calculation see Fox, Hunn & Mathers, 2007; De Vaus, 2014; Fowler, 2013; Pazzaglia, Stafford & Rodriques, 2016). In a book by De Vaus (2014) on survey research methods the author outlined some key terms in survey research methods that have technical meanings, and it is important to understand these terms before discussing sampling techniques. These terms include a *census, population*, a *sample* and *sampling frame*. In survey terminology a *census* is obtained by collecting information about every member of a group that is the *population*. *Population* refers to the set of members that the sample is meant to represent. The population is usually defined by the researchers for the study. A *sample* is obtained by collecting information about some members of the population. Once the target population has been established for the study, the next step is to obtain a *sampling frame*, which is a list of the population members. From this list we obtain a sample using an appropriate sampling technique. In addition, it is important that the term target population is not confused with study population. The study population is the population whom we want to study about, whereas the target population is the population that will complete the study research questions.

Fox, Hunn and Mathers (2007) outlined that in some situations it is not necessary to select a sample. If the study population are rare, or make up 1000 or less, then the researchers might decide to survey every population member. There are two crucial steps in survey research studies which attempt to make generalisation from the study results to the wider target population. These are sampling and sample size calculation (Fox, Hunn & Mathers, 2007). There are two broad sampling techniques, including random (probability) sampling and non-random (non-probability) sampling. There are different probability sampling methods including simple random sampling, systematic sampling, stratified random sampling, cluster (or multistage) sampling (Fox, Hunn, Mathers, 2007; De Vaus, 2014). Often given the needs of the study, researchers might combine and use more than one sampling technique known as complex sample designs (i.e., multistage cluster sampling) (Chapter 3).

In the following section we describe these two crucial survey steps within the context of our own surveys undertaken for the current thesis, and outline how we employed these for our survey studies with school students and teachers (Chapters 2 and 3).

A pilot survey of secondary school science leaders' understanding and recommendations of study and revision strategies for science

We were interested in first exploring science subject leaders' understanding and recommendations of learning strategies to students for science revision from a representative sample of science teachers in secondary schools in North Wales. In survey research methods an important first step is to clearly define the target population (i.e., say who is a member and who is not a member) (De Vaus, 2014). We defined the target population for our study with science subject leaders as school teachers responsible for the science department in mainstream secondary schools in North Wales. There are fifty-four maintained secondary schools in North Wales, with one science teacher appointed as the subject leader in each school. Thus, there were fifty-four science subject leaders in North Wales. Given the small number of science subject leaders it was not necessary to select a sample nor was it necessary to calculate a sample size (Fox, Hunn & Mathers, 2007). In this circumstance we planned to complete the survey with every member of the target population. In survey research methods a survey which involves inviting every member of the target population is informally known as a census non-response survey. We undertook our survey with the science subject leaders at the biannual heads of science forum meeting in October 2018. As we were able to contact the science subject leaders directly at the meeting (and could obtain a list of the teachers email contacts from our project partners), there was no complex survey design. Within chapter 2 we present our survey study with science subject leaders in North Wales.

A Survey of Secondary School Students' Use and Understanding of Study and Revision Strategies for Science Examinations

We wanted to explore secondary school students' use and understanding of learning strategies. For this survey we used a multistage implicitly stratified sampling method for a sample selection and the objective of the survey was to gather responses from a representative sample of students attending secondary schools in North Wales (Chapter 3). The survey was designed in three phases as follows:

Step 1: Defining the target population

First, we defined the target population for our survey with students as school students aged between 14 and 15 years studying external science qualifications (i.e., GCSE's or BTEC) in mainstream secondary schools in North Wales. Following ethical approval, we obtained a list of all the secondary schools and student (numbers) from the North Wales Regional School Improvement Service. In survey terminology this list is known as the sampling frame.

Step 2: Sample size calculation

In the academic year 2018/2019, there were 6,900 school students in Year 10 studying GCSE science in mainstream maintained secondary schools in North Wales. A survey with all students in Year 10 was not practical due to the financial and logistical demands. In addition, a challenge of applied research in school settings often requires removing students from timetabled lessons. Therefore, it was important to find a way of reducing the number of students to include in the study without biasing our survey findings. At the time of designing the survey we could find no guide on sample size calculation for surveys in education research. A precise mathematical formula is available for calculating the sample size in clinical research which we used for our survey with students (e.g., the Sampling and Sample size Calculation guide produced by the National Institute for Health Research Research Design Service, 2007). We calculated a sample size of 924 school students aged between 14 and 15 years following statistical guidelines in the Sampling and Sample size Calculation guide produced by the National Institute for Health Research Research Design (Fox, Hunn & Mathers, 2007), as well as advice on the calculation from a survey statistician. We planned our sample size on a student population of 6,900, with a desired precision of 0.03, and using the most conservative assumed element variance with a 95% confidence interval. The sample size formula and calculation for our survey with students is contained within Appendix B.

Step 3: Sampling

We used a multistage implicitly stratified sampling method to generate a sample selection. In the first stage of the sampling process, we invited all fifty-four mainstream maintained secondary schools in the six local authorities in North Wales to participate in the survey. This ensured all schools in the region irrespective of size, language category and geographical location participated. In the second stage, we selected a sample of students proportionate to the total number of students in the Year 10 cohort from an anonymised list of students provided by each of the 29 schools that replied.

To ensure that the sample of students represented different ability levels, we employed a stratified sampling method. We asked the school science contact to order the anonymised list of students according to the science qualification they were studying (e.g., all students studying triple GCSE science were listed first, followed by all students studying double GCSE science and then all students studying BTEC and/or applied GCSE science). The science qualification information was then used as an indicator of students' academic ability in school science (i.e., more academically able students typically follow the triple science award, with the remaining students generally following the double science and BTEC and/or applied science qualifications). Every *n*th student was then selected on the list (after a random starting point was generated). This allowed every eligible school student an equal chance of selection and allowed representation of each ability level in the final sample for each school in its correct proportion.

The Influence of the COVID-19 Pandemic on the Progress of Students' Independent Learning Practice in Wales

This survey evaluated the influence of the COVID-19 pandemic on secondary aged students' independent learning practice and was commissioned by the Welsh Government. During the COVID-19 lockdown school closures resulted in the vast majority of students completing school work from home. Given that students were learning from home we were interested in exploring the influence of the pandemic on students' independent learning practice. For our survey with students during the pandemic we used a multistage clustered sample design for a sample selection. The target population for our second survey with secondary learners was students aged 14–15 and 16–17 years (Year groups 10 and 12) in mainstream middle and secondary schools in Wales. We used a different sampling method to our previous survey with secondary students due to different study populations and aims (i.e., multistage clustered sample design). Our second study with students was a larger survey involving mainstream schools with students aged 11 to 16 across Wales. An advantage of this sampling approach (i.e., multistage clustered sampling) was that it was practical and would help minimise disruption and would not create any additional work for schools in terms of providing lists of classes, students.

Survey weights

An advantage of using probability sampling methods is that researchers can make several survey weighting adjustments to compensate for survey non-response and for unequal selection probabilities (to ensure the findings better represent the population it is designed to represent). Survey weights are also used for surveys involving more complex sampling methods. The use of survey weights is discussed further in Chapter 3.

Complex samples analysis

For surveys using complex sample designs (i.e., multistage sampling), it is important to analyse the data using software programmes which incorporate the survey design and any additional variables (i.e., weighting variable, cluster variable, stratification variable) to produce correct estimates. Without these the estimates will not be accurate. The survey data were analysed using SPSS Complex Samples (version 25). In addition, we also used the 'survey' package in R for analysing complex samples described in Chapter 3. It is worth noting that there is a paucity of useful research articles and guides on using SPSS Complex Samples, there is a useful article by Zou et al. (2020). In addition, there have been some useful video guides on how to use SPSS Complex Samples (European Social Survey, 2021).

Randomised controlled trials in education

The two most commonly used experimental designs for a randomised controlled trial (RCT) in education research include either simple or cluster randomisation (Connolly et al., 2017). In the simple/individual design, students are assigned to condition of intervention or control at the individual level. In the cluster RCT the school or class will be the unit of study with intervention delivered to an entire class or even school. In education research trials the clustered RCT design is a more widely adopted design because students are grouped in classes as part of their daily school activities, to minimise any unnecessary class disruption and because often it is practically not possible to separate students individually for the purpose of a trial during timetabled school lessons.

Our survey studies presented within Chapters 2 and 3 suggested that students would benefit from receiving training in effective learning strategies. Our surveys also indicated that both students and teachers were interested in students receiving more information about effective learning strategies to help students with independent learning. Within Chapter 4 we describe the learning resource we developed called improving standards through effective revision (iStER) and report our evaluation of the lunchtime study/revision programme to learn GCSE chemistry using the learning resource in an individually randomised feasibility controlled efficacy trial with secondary school students in North Wales. The iStER learning resource is aimed at secondary school students aged 14–16 years. The iStER programme is designed to inform students about evidence-informed learning strategies, as well as raise awareness about and normalise independent learning (i.e., study/revision). The iStER programme furthermore provides a system and materials, iStER resource packs, to help students to apply effective learning strategies (i.e., spaced practice and retrieval practice), using evidence informed approaches (i.e., Leitner system) and organise their independent learning. The programme ran for 5 weeks and was delivered by the research student. In total thirty-four students were recruited for the efficacy trial, and were then randomly allocated, on an individual basis, to the intervention, chemistry study, or waiting list control groups.

Given that the learning resource was new and had not been evaluated prior, it was important to undertake a small-scale study with one secondary school. A clustered RCT design with one school and student classes as the unit of study, would have resulted in contamination through peer learning. However, adopting a clustered RCT design would require more than one school, at this stage our aim was to assess feasibility rather than evaluate effectiveness. For such reasons we designed the lunchtime study/revision sessions for students to use the iStER learning resource with all resources collected by the research student at the end of each session. Given that the sessions were organised outside of timetabled lessons (i.e., during lunchtime) it was possible to separate students individually for the purpose of our efficacy trial.

Chapter 2: A Pilot Survey of Secondary School Science Leaders' Understanding and Recommendations of Study and Revision Strategies for Science

Preface

There is currently a lack of research surrounding the learning strategies teachers in schools encourage students to use for study/revision, and into teachers' understanding of evidence-informed learning strategies. In this chapter we present a survey in which we investigated the recommendation and understanding of evidence-informed learning strategies among science subject leaders, teaching science in secondary schools in North Wales. Our results showed that there is no clear trend on which learning strategies science teachers in secondary schools promote, teachers reported that they encouraged the use of a mixture of common learning strategies, including both low and high utility strategies. Our findings have important implications for schools, policymakers, providers of initial teacher education programmes. It is important for the relevant stakeholders to know that teachers in schools are clearly promoting high utility strategies, however, they also promote lower utility strategies, and have a moderate understanding about the utility of effective learning strategies.

Introduction

The use of effective learning strategies can play an important role in the learning outcomes students achieve. Research suggests that two strategies, retrieval practice and spaced practice, are more effective for improving learning outcomes for students (Agarwal et al., 2021; Dunlosky et al., 2013; Karpicke & Roediger, 2006). Despite the growing evidence supporting effective learning strategies, there is a lack of empirical research on the recommendations of learning strategies provided by school teachers to students in mainstream educational settings for independent learning (Surma et al., 2022). Furthermore, very little research has reported on teachers' understanding of effective learning strategies (Perry et al., 2021; Surma et al., 2022). The present study aims to address this research gap by conducting a survey with secondary school science subject leaders (senior teachers) to explore their understanding of common learning strategies, and what strategies they promote to students. The primary aims of this study were to evaluate: (1) Which learning strategies do secondary school teachers promote to help students study and/or revise in preparation for science examinations? (2) What is teachers knowledge of learning strategies (i.e., what teachers understand to be the most- and least-effective learning strategies and their views about the research evidence supporting common learning strategies)? The secondary aim of this study was to identify how schools support teachers to encourage students to use these strategies?

What are learning strategies?

Learning strategies can be described as the methods students use to promote learning and understanding of key content and ideas on their own, usually in preparation for low stakes and/or high stakes summative assessments. In an important review of the research evidence on learning strategies, Dunlosky et al. (2013) evaluated ten commonly used learning strategies and arranged these into low, medium and high utility categories based on how effective the strategies generalise across a range of key variables (e.g., learning conditions, student characteristics, materials and criterion tasks). Two strategies were identified as high utility (practice testing [note that we use the term retrieval practice here to include all activities involving the recall of information from memory] and distributed practice [note that we use the term spaced practice here]), three strategies were identified as having moderate utility (interleaved practice, elaborative interrogation and self-explanation), and five strategies were identified as having low utility (summarising, highlighting [or underlining], using keyword mnemonics, imagery use for text learning and repeatedly reading information). These findings have important implications for effective study strategy use by students in schools.

Teachers use and understanding of learning strategies

Teachers in schools are the main source of information and ideas about the academic subject being studied, and also an important source of information about how best to learn and revise for tests and examinations. Given teachers' critical role in all aspects of learning, it is important to understand more about what study approaches they recommend to students. Much of the existing research in this area has been limited to surveys of higher education instructors' recommendations of learning strategies to university students (McCabe 2018; Piza, 2018; Morehead et al., 2016). Studies in university settings showed higher education instructors promote the use of both less and more effective learning strategies to students (i.e., retrieval practice activities, repeatedly read information, and outlining information while reading) (McCabe 2018; Piza, 2018; Morehead et al., 2016). To date, there are few studies that have evaluated secondary school teachers' recommendations of commonly used learning strategies to school aged students (Surma et al., 2022). Surma et al. 's (2022) survey of newly qualified secondary school teachers showed most respondents reported recommending summarising (i.e., a low learning strategy) and less than half recommended using retrieval practice (i.e., more effective learning strategy).

A key factor that might influence whether effective learning strategies are promoted and are successfully implemented by educators include their understanding of learning strategies (i.e., what educators understand to be the most- and least-effective learning strategies and their views about the research evidence supporting common learning strategies). Studies in university settings have showed that higher education instructors have a moderate understanding of evidence-informed learning strategies, and primarily promote retrieval practice (i.e., an effective learning strategy) to students as a means to assess their learning (i.e., to obtain feedback on their learning) and not as a method to promote actual learning and understanding (McCabe 2018; Piza, 2018; Morehead et al., 2016). McCabe (2018) asked heads of academic support centres to rate how effective they believed various learning strategies promoted to students were for study. Findings showed instructors ranked retrieval practice and spacing practice (i.e., higher utility learning strategies) as effective for study. However, other less effective strategies were also rated as effective by these instructors (i.e., reading course materials).

In a recent study with school teachers, Surma et al. (2022) assessed secondary school teachers' knowledge of effective learning strategies and found that these teachers understood the effectiveness of evidence-informed learning strategies such as retrieval practice, spaced practice and interleaving. However, Surma et al.'s (2022) survey also found these effective learning strategies were recommended less frequently by secondary teachers. The authors noted that the inconsistency between novice teachers' recommendation and understanding of effective learning strategies may be due to the question format in such surveys (e.g., open-format with teachers reporting the strategies, or closed-format with teachers selecting strategies from a predefined list) might influence teachers reports of strategy use. In Surma et al.'s (2022) survey, the question on recommending learning strategies was an open-ended question in which teachers had to list the three learning strategies they would recommend to students which required recall from memory without any prompt. In contrast, their survey question on the effectiveness of the learning strategies was a closed question in which the effective strategies were listed, therefore only required recognition, which might have acted as a prompt for teachers.

In an earlier study, Perry et al. (2021) explored school teachers' understanding of five evidence-informed learning strategies, including spaced practice, interleaved practice, retrieval practice, dual encoding, and strategies to manage cognitive load. Findings showed that school teachers reported that they have higher knowledge of retrieval practice compared to spaced practice and interleaved practice. Perry et al. (2021) also asked teachers to rate how important they believed the strategies were for effective teaching and learning, and found retrieval and spaced practice were rated as being most important for effective teaching by the highest proportion of teachers. Their study also revealed that most of the teachers believed that there is firm scientific evidence to support all or most of the strategies investigated in their study. However, Perry et al.'s survey did not report on teachers use, nor their understanding of, a variety of other commonly used learning strategies in education (i.e., those recently evaluated by Dunlosky et al. [2013]), nor on the recommendations of strategies teachers make to students for independent revision. In addition, their survey used convenience sampling, as opposed to a random sample of teachers. It is possible, therefore, that their results were biased towards over-representation of teachers who were more interested in the application of cognitive science strategies in schools, and evidence-informed learning strategies in general (a caveat also mentioned by the authors).

In the current study we focused on the learning strategies that relate to *how* students learn. These strategies included those recently evaluated by Dunlosky et al. (2013). Prior survey research on the implementation of learning strategies by instructors in educational settings has assessed how educators recommend various study skills and lifestyle habits (e.g., time management skills, studying with friends) alongside the learning strategies (Piza, 2018; McCabe, 2018; Morehead et al., 2016). Although study skills are important factors for promoting learning and achievement in students, it is important to make the distinction between aspects of study concerned with lifestyle and study skills and those concerned with learning strategies alone (i.e., *how* students learn). Importantly, this will help us understand the extent to which teachers' recommendations of learning strategies are consistent with the evidence base in this field.

Methods

Participants

The target population for the current survey was science teachers who are the subject leaders for science in secondary schools in North Wales. There are 54 local authority maintained secondary schools in the region, and this study aimed to survey all fifty-four heads of science. This approach was taken due to the availability and convenience of being able to meet all the science leaders during their regional forum meeting where it was possible to administer the survey in person. The cross-sectional survey was carried out by the first author at the autumn term biannual heads of sciences forum meeting in October 2018. Ethical approval for this study was obtained from the Research Ethics Committee of Bangor University (ethical approval number: 2018-16316), and all survey materials were made available in both English and Welsh.

Ethics

Ethical approval for this study was obtained from the Research Ethics Committee of Bangor University (ethical approval number: 2018-16316), and all survey materials were made available in both English and Welsh.

Survey procedure

A convenient time was arranged to conduct the survey with the science subject leaders during their regional meeting. The first author explained the purpose of the study and presented the participants with information about the study and obtained written informed consent from all the participants. The survey questionnaire was issued in paper format to be completed during the meeting. To conclude, all participants were given a verbal debrief about the study together with a study debrief handout. Completion of the survey questionnaire was self-paced and the participants required approximately ten minutes to complete the questionnaire. Participation in the survey was voluntary, and the science teachers were not remunerated for their participation in the survey.

Survey measure

We used the Effective Revision and Study Strategies Questionnaire (ERaSSQ) developed for teachers with the science subject leaders. We created the ERaSSQ survey using an online survey software programme named Online Surveys (https://www.onlinesurveys.ac.uk/). We developed the questionnaire to measure secondary school teachers' understanding of evidence-informed learning strategies and how they recommend these to school students. The survey items were developed following a review of the literature on instructor and student understanding, and recommendation of learning strategies (Blasiman et al., 2017; Kornell and Bjork, 2007; McCabe, 2018; Morehead et al., 2016; Piza, 2018).

The format of the survey items were closed-ended with a predefined set of ten learning strategies, and open-ended to give science subject leaders the opportunity to report any additional information about the learning strategies they promote. Of the learning strategies listed in the survey items, seven were identified from Dunlosky et al.'s (2013) review of common learning strategies. These strategies are: *highlighting and/or underlining information or text; repeatedly reading information or notes, making notes (summarising), spaced practice, doing practice tests, interleaved practice, keyword mnemonic*. Three additional learning strategies identified in the literature, and commonly used by students/promoted in schools were also included in the survey; *using flashcards*, *using mind maps* and *elaborate encoding*. The questionnaire was piloted to a convenience sample of six science teachers, teaching at two secondary schools in North Wales in July 2018. Following the pilot of the survey, the survey items were revised with new items added to obtain a more comprehensive insight into science teachers' understanding of evidence-informed learning strategies.

The final version of the survey consisted of 16-survey items divided into three sections: Section One contained 6 items, and asked about recommendations of learning strategies provided by teachers, as well as teachers' understanding of learning strategies (i.e., knowledge of effective learning strategies, what teachers understand to be the most and least-effective strategies and views of the research evidence supporting learning strategies); Section Two contained 6 items, and asked about school based support for teachers to help students with revision (i.e., sharing good revision practice with teachers, availability of information about learning strategies,), as well as demand for information about evidence-informed learning strategies; and, Section Three contained 4 items which covered demographic information (i.e., number of year(s) working in current position, number of year(s) working as a science teacher, field of science speciality and highest level of education). A description of the survey items from the teacher version of the ERaSSQ is given below.

Survey item one measured how often teachers promote the ten common learning strategies to students in their science class. For this survey item, teachers were presented with the ten learning strategies and were asked to indicate on a 5-point Likert scale, from never (1) to always (5), how often they recommended each of the listed learning strategies to students in their science class. The teachers also had the option to list a learning strategy(ies) that was not mentioned in the list (*survey item two*).

Survey item three measured the teachers' understanding/beliefs about the effectiveness of the common learning strategies. For this survey item, teachers were presented with the ten learning strategies and were asked to indicate on a 5-point scale, from not effective (1) to extremely effective (5), how effective they believed the learning strategies listed were for students to learn science. The teachers also had the option to list a learning strategy(ies) that was not mentioned in the list (*survey item four*).

Survey item five measured the teachers' views on the research evidence supporting the ten learning strategies. For this survey item, teachers were presented with the ten learning strategies and were asked to indicate on a 5-point Likert scale, from not sure (1) to strong research (5), what their views were on the research evidence supporting the learning strategies listed.

Survey item six measured the teachers' understanding of retrieval practice. For this survey item, teachers were told to imagine that they have finished teaching a science topic and are planning to administer a science assessment to students, and were then asked to choose one of three options that best reflected their reason for why students should complete the assessment (i.e., a form of retrieval practice activity). Existing research suggests that retrieval practice activities can be used in more than one way (i.e., as a diagnostic tool to evaluate learning or as an effective learning strategy), it was therefore important for us to assess the teachers primary motive for promoting retrieval practice activities to students.

Survey item seven measured whether teachers discuss effective learning strategies with their colleagues (i.e., share good practice) to help students with science revision. For this survey item the teachers were asked to indicate using a ‘yes’ and ‘no’ response whether they discussed learning strategies with their science colleagues.

Survey item eight measured support for teachers about learning strategies (i.e., information on evidence-informed learning strategies). For this survey item the teachers were asked to indicate using a ‘yes’ and ‘no’ response whether they are being provided with information about learning strategies. The teachers also had the option to mention the name(s) of the key provider(s) of this information on learning strategies (*survey item nine*). The final survey items *(survey item ten and eleven)* measured the demand for information about effective learning strategies to help students with revision.

Data analysis

During survey administration, a typographical error on the wording of the response scale for survey item one was identified (i.e., response option 2 [very often] was missing the word ‘not’, it should have read ‘not very often’ to mean ‘rarely’). As a result, the response categories for survey item one were collapsed following guidelines in the Surveys in Social Research textbook (De Vaus, 2014). Instead of using survey item one to measure how often the heads promoted the common learning strategies, it was modified to measure rather if the teachers promoted the use of the learning strategies listed. Using this approach, the response options 2 (very often), 3 (sometimes), 4 (most of the time) and 5 (always) were combined into one new category (i.e., did recommend the strategy) and the original first response option (never) was reclassified as did not recommend the strategy. This approach was adopted contrary to treating the data as contaminated data, as this survey question provided valuable information on how school teachers recommend more- and less effective learning strategies. We subsequently inputted and analysed the data using SPSS (version 25). No weighting procedure was used.

Analysis of open-ended responses

The analysis aimed to identify additional learning strategies teachers promote to students for revision. All responses to the open-ended questions were initially analysed by the first author to develop a draft list of categories to classify the responses into. Instructions about the new categories alongside all the responses were then provided to the second author to independently classify into the categories. Agreement was assessed and any discrepancies discussed with changes made to the categories if necessary. Once the categories were finalised the first author classified all the responses into the new categories.

In addition to the ten learning strategies listed in the ERaSSQ survey for teachers, we gave teachers the opportunity to report any additional learning strategy(ies) they recommended to students. The first author evaluated all responses to the open-ended questions and constructed separate categories for responses that were not one of the ten learning strategies assessed in the survey. Although some of the teachers' responses were considered to be examples of one of the ten listed strategies (e.g., to make notes, to use retrieval practice), we decided to construct separate categories for all the open-ended responses as this provided valuable information on how teachers adapt strategies they promote, and on teachers' understanding of learning strategies.

Results

Response rates

In total, 35 science subject leaders participated in the survey, generating a total of 35 completed questionnaires. This represents a response rate of 64.8 per cent. The characteristics of the participating science teachers are presented in Table 2.1.

Table 2. 1 *Characteristics of the participating science subject leaders*

		Participating science teachers	
	Variable	*n*	%
Education (highest level)	Bachelor's degree	6	17.1
	PGCE*	22	62.9
	Master's degree	5	14.3
	Doctoral degree	2	5.7
Subject (primarily teaching)	Biology	16	47.1
	Chemistry	13	38.2
	Physics	5	14.7
Year(s) working as science teacher	6 to 10 years	5	14.3
	11 to 15 years	7	20.0
	16 to 20 years	11	31.4
	21 to 25 years	7	20.0
	26 to 30 years	3	8.6
	Over 30 years	2	5.7
Year(s) working as science subject leader	0 to 5 years	22	62.9

	Participating science teachers	
Variable	*n*	*%*
6 to 10 years	6	17.1
11 to 15 years	6	17.1
Over 20 years	1	2.9

Note. *PGCE = Post Graduate Certificate in Education. PGCE is an academic qualification designed for prospective primary and secondary school teachers in the UK.

Which learning strategies do secondary school science subject leaders promote to school students for revision?

The primary aim of this survey was to assess which learning strategies secondary school science leaders recommended to students for science revision. Table 2.2 shows the 10 learning strategies, and the percentages of science teachers reporting recommending (or not recommending) the learning strategies, arranged from most to least recommended.

Table 2. 2 *Presents the frequencies and percentage scores for science leaders' recommendations of the common learning strategies (Survey Item One)*

Learning strategy	Recommend		Do not recommend		Total	
	n	*%*	*n*	*%*	*n*	*%*
Making notes (summarising)	34	100.0			34	97.1
Doing practice tests	34	100.0			34	97.1

Learning strategy	Recommend		Do not recommend		Total	
	n	%	*n*	%	*n*	%
Using mnemonics	34	100.0			34	97.1
Highlighting/underlining notes/information	34	100.0			34	97.1
Spaced practice	33	97.1	1	2.9	34	97.1
Repeatedly reading information/notes	33	97.1	1	2.9	34	97.1
Using mind maps	32	97.0	1	3.0	33	94.3
Using flashcards	31	91.2	3	8.8	34	97.1
Elaborate encoding	28	84.8	5	15.2	33	94.3
Interleaved practice	28	82.4	6	17.6	34	97.1

Note. Doing practice tests is a form of retrieval practice activity. We use the term practice tests to refer to retrieval practice. We used the term spaced practice to refer to distributed practice. Learning strategies are arranged from most to least recommended, based on percentage scores. Data are analysed at the individual level.

The qualitative data from the free responses-question about any additional learning strategy(ies) that the science teachers reported promoting to students to use for science revision were classified into eight categories, and the percentage of teachers with a response in each category was computed (*survey item two*). The eight categories, including examples from each category, are presented below.

To complete other retrieval practice activities using offline learning resources. Of the respondents, four (16.7%) subject leaders reported that they recommended students to undertake other retrieval practice activities (i.e., any activity involving recall of information from memory). For example, being tested by others, completing quizzes/past paper questions, peer to peer questioning, and so forth.

To use online and/or smartphone learning resources (e.g., BBC Bitesize, GCSEPod, WJEC) or offline learning resources (such as revision guides). A total of eight (33.3%) subject leaders reported that they recommended students to use web-based and/or smartphone learning resources without specifying how these learning resources were promoted to learn the content (e.g., revision apps, BBC Bitesize, web based apps, online activities).

To use online learning resources to complete retrieval practice activities. A total of two (8.3%) subject leaders reported that they recommended students to use web-based and/or smartphone learning resources to complete retrieval practice activities (e.g., Kahoot, completing multiple choice quizzes online, completing retrieval activities using Roulette).

To watch and/or listen to learning resources. A total of five (20.83%) subject leaders reported that they would recommend students to watch and/or listen to learning resources (e.g., on YouTube, Twigworld, Khan academy).

To make notes. In total two (8.3%) subject leaders reported that they would recommend students to make notes using post-it/sticky notes and colour coding notes.

To teach and/or study with others. In total three (12.5%) subject leaders reported that they also promoted students to teach others and/or study with others (e.g., peers, friends, family, study groups).

To complete skills development activities. In total six (25.0%) subject leaders reported that they also promoted students to complete activities to develop exam skills (e.g., knowing the skills needed to perform well and/or to answer questions, knowing the command words).

Other activities. In total one (4.2%) subject leader reported promoting one of the common learning strategies assessed in the present study in a different way (e.g., colour coding notes).

Teachers' ratings of the effectiveness of common learning strategies (what do teachers understand to be the most- and least-effective learning strategies?)

In this survey, we also aimed to evaluate what science teachers' understand to be the most- and least-effective learning strategies. Table 2.3 shows the 10 learning strategies, and the teachers' ratings of their perceived efficacy of the learning strategies for learning (higher mean scores indicated that the teachers rated the strategy as more effective).

Table 2. 3 *Presents the mean scores for science leaders' perceived efficacy of the learning strategies (Survey Item Three)*

Learning strategy	$\bar{x}$	*SE*
Doing practice tests	4.32	0.1
Spaced practice	3.93	0.1
Elaborate encoding	3.82	0.1
Using flashcards	3.57	0.1
Making notes (summarising)	3.50	0.2
Interleaved practice	3.43	0.2
Using mind maps	3.18	0.1

Learning strategy	$\bar{x}$	*SE*
Repeatedly reading information/notes	3.11	0.2
Highlighting/underlining information/notes	3.07	0.2
Using mnemonics	3.07	0.2

Note. Teachers' ratings of their perceived efficacy of the listed learning strategies were made on a 5-point scale, from not effective (1) to extremely effective (5). Higher scores indicated that the teachers rated the learning strategies as more effective.

The qualitative data from the free response-question about any additional learning strategy(ies) that the teachers reported that they believed were effective were also classified into six broad categories (*survey item four)*. The six categories, including examples from each category, are presented below.

To complete other retrieval practice activities using offline learning resources. Of the respondents, three (37.5%) subject leaders reported that they believed undertaking other retrieval practice activities were effective (i.e., any activity involving recall of information from memory). For example, being tested by others, completing quizzes/past paper questions, peer to peer questioning, and so forth.

To use online and/or smartphone learning resources (e.g., BBC Bitesize, GCSEPod, WJEC) or offline learning resources (such as revision guides). In total two (25.0%) subject leaders reported that they believed using web-based and/or smartphone learning resources without specifying how these learning resources were effective to learn the content (e.g., revision apps, BBC Bitesize, web based apps, online activities).

To use online learning resources to complete retrieval practice activities. In total one (12.5%) subject leader reported that they believed using web-based and/or smartphone learning resources to complete retrieval practice activities were effective (e.g., Kahoot, completing multiple choice quizzes online, completing retrieval activities using Roulette).

To watch and/or listen to learning resources. In total one (12.5%) subject leader reported that they believed watching and/or listening to learning resources were effective (e.g., on YouTube, Twigworld, Khan academy).

To teach and/or study with others. A total of two (25.0%) subject leaders reported that they also believed students teaching others and/or studying with others were effective (e.g., peers, friends, family, study groups).

To complete skills development activities. A total of two (25.0%) subject leaders reported that they believed completing activities to develop exam skills were effective (e.g., knowing the skills needed to perform well and/or to answer questions, knowing the command words).

What are secondary school science teachers' understanding about the research evidence supporting common learning strategies?

To measure science subject leaders' understanding of the research evidence supporting the 10 learning strategies, we asked the teachers to indicate how much research evidence they think there exists to support using the 10 learning strategies. Table 2.4 shows the 10 learning strategies, and teachers' ratings of how much research evidence they think there exists to support the learning strategies for learning (higher mean scores indicate that the teachers rated the strategy as being more evidence-informed).

Table 2. 4 *Presents the mean score for science leaders' understanding of the research evidence supporting learning strategies (Survey Item Five)*

Learning strategy	$\bar{x}$	*SE*
Doing practice tests	3.34	0.3
Elaborate encoding	3.10	0.3

Learning strategy	$\bar{x}$	*SE*
Repeatedly reading information/notes	2.97	0.2
Making notes (summarising)	2.97	0.2
Keyword mnemonics	2.97	0.3
Spaced practice	2.93	0.3
Using flashcards	2.90	0.2
Using mind maps	2.90	0.2
Interleaved practice	2.79	0.3
Highlighting/underlining information/notes	2.38	0.2

Note. Teachers' ratings on their understanding of the research evidence supporting the listed learning strategies were made on a 5-point scale, from not sure (1) to strong research (5). Higher scores indicate that the teachers rated the learning strategies as having more robust evidence (i.e., evidence-informed).

Teachers' understanding of the benefit for using retrieval practice

Table 2.5 shows the various reasons teachers might promote doing summative assessments (i.e., a retrieval practice activity), and the percentages of teachers endorsing each option. Note that we used the term summative assessments in the ERaSSQ because this is a common form of retrieval practice activity teachers use.

Table 2. 5 *Presents the percentage scores for science leaders' reasons for promoting retrieval practice activities to students (Survey Item Six)*

Response option (reason)	%
Doing a assessment will help the pupils learn more than through reading over and over	12.1

Doing a summative assessment will help pupils figure out how well they have learnt the information they are studying	81.8
I do not think doing a summative assessment will necessarily benefit the pupils	6.1

Do secondary science subject leaders discuss learning strategies with their science colleagues? Are secondary school science teachers currently being provided with support (i.e., information about evidence-informed learning strategies) to help students with revision? Is there a demand for information about evidence-informed learning strategies?

To further evaluate whether there is a need to provide additional information and support to teachers on evidence-informed learning strategies, we asked teachers about the current provision of learning strategies in schools (*survey item seven, nine, eleven and twelve*). Table 2.6 shows the percentages of science subject leaders who reported whether they discussed learning strategies with their colleagues in the science department, the percentages of teachers reporting whether teachers were being provided with information about learning strategies, and percentages of teachers interested in receiving information about evidence-informed learning strategies.

Table 2. 6 *Percentage scores for science leaders' responses to the survey questions about current provision and demand for evidence-informed learning strategies (Survey Item Seven to Twelve)*

Survey item	Response option	*n*	%
Do you discuss revision strategies with your colleagues in the science department?	Yes	33	100.0
	No		

Survey item	Response option	*n*	%
Do you think science teachers are being provided with information about revision strategies?	Yes	17	51.5
	No	16	48.5
Do you think there is currently a need to provide science teachers with information about effective revision strategies?	Yes	35	100.0
	No		
Would you be interested in obtaining information about evidence-based revision strategies to help pupils learn science more effectively?	Yes	34	97.1
	No	1	2.9

We aimed to identify where teachers' knowledge of learning strategies came from by asking teachers to list all the sources that had provided them with information about revision strategies. We identified six sources that had provided science subject leaders with: information about revision strategies. The organisations were (1) higher educational institutions; (2) examination boards; (3) school improvement service providers; (4) school based support; (5) Social media platforms, researcher-driven websites and fora; (6) their own enquiry based research.

Higher education institutions. A total of three (21.4%) subject leaders reported that they were being provided with information on revision strategies from higher education institutions (e.g., Bangor University).

Examination boards. A total of five (35.7%) subject leaders reported that they were being provided with information on revision strategies from examination boards (e.g., WJEC).

School improvement service providers. A total of eight (57.14%) subject leaders reported school improvement service providers (e.g., the School Improvement Service for North Wales [GwE]) provided them information on revision strategies.

School based support. A total of three (21.42%) subject leaders reported schools provided them information on revision strategies (i.e., sharing good practice with colleagues, sharing good practice between schools).

Social media platforms, researcher-driven websites and fora. In total three, (21.42%), subject leaders reported they obtained information on revision strategies from social media platforms and researcher-driven websites and fora (e.g., Twitter, CogSciSci [https://cogscisci.wordpress.com/]).

Teachers' own research. In total one (7.14%) subject leader reported they obtained information on revision strategies from their own research.

Discussion

In this study, we report results of the first survey to assess the learning strategies science subject leaders promote to school students for science revision in the UK, as well as teachers' understanding and awareness of the research evidence supporting these strategies.

What learning strategies do teachers promote?

Our results showed that science subject leaders promoted the use of retrieval practice and spacing practice (i.e., more effective learning strategies) and these strategies were rated as being effective strategies by the teachers. Less effective learning strategies (i.e., highlighting and/or underlining notes or information and repeatedly reading information) were also promoted by most of the science subject leaders. However, these strategies received lower ratings for effectiveness from the science subject leaders. These findings align closely with the outcomes reported by Piza (2018), McCabe (2018) and Morehead et al. (2016) who found that instructors reported recommending both less- and more-effective learning strategies to students. Due to the typographical error, we could not evaluate how often teachers promoted the common learning strategies. Future research evaluating how often teachers promote common learning strategies will provide a more useful indicator of the strategies promoted by teachers.

Teachers understanding of learning strategies

The findings from this study show that science subject leaders perceived completing practice tests and spaced practice (i.e., effective strategies) as effective learning strategies, and repeatedly reading information and highlighting and/or underlining notes or information (i.e., less effective strategies) as moderately effective strategies. This study is the first to report on secondary school teachers' self-reported beliefs about the effectiveness of learning strategies. An earlier study by McCabe (2018) on heads of academic support centres beliefs about the efficacy of learning strategies revealed that instructors ranked completing practice tests, making notes and spacing practice as effective strategies, and repeatedly reading information, highlighting and/or underlining notes as moderately effective. In Dunlosky et al. 's (2013) review of learning strategies, only practice testing and spaced practice received high utility ratings (i.e., were more likely to be useful for learners as effective learning strategies). Our findings on secondary school teachers' perceived efficacy of learning strategies align with the findings of McCabe (2016) and suggest that school teachers have a moderate understanding of the effectiveness of learning strategies.

Our study also included data on science subject leaders' understanding of the research evidence supporting learning strategies. The results showed that most of the subject leaders' are aware of the research evidence underlying the ten listed learning strategies. There were minor differences in subject leaders' perceptions of the research evidence between the learning strategies.

Although our data showed that science subject leaders perceived completing practice tests (i.e., effective strategy) as an effective learning strategy, results from our study also revealed that the majority (81.8%) of the teachers reported that they promote summative assessment to help students evaluate their learning (i.e., to identify what they know and/or don't know). Similarly, data from Piza (2018) and Morehead et al. (2018) on university instructors' reasons for recommending practice tests revealed that most of the instructors reported that they promoted practice tests to students due to the benefits of receiving diagnostics feedback from completing the tests. Teachers' recommendation of retrieval practice-based activities to help students evaluate learning may be because teachers have traditionally used tests and quizzes (i.e., different forms of retrieval practice activities) for formative and/or summative purposes (i.e., for assessing student learning). Therefore, teachers might not be aware of the advantage of promoting retrieval practice as a learning strategy in itself. These findings highlight the need to inform secondary school teachers about the learning advantage of retrieval practice activities.

Our current study has important policy and practice implications for both schools, school improvement professionals and also providers of teacher initial education. For providers of teacher initial education it is important that course programmes equip early career teachers with the relevant knowledge and understanding about more effective learning strategies. Our results also suggest that secondary school teachers would benefit from receiving training about effective learning strategies to help students study and revise more effectively. Importantly, findings from this study also indicate that secondary teachers would welcome more information and guidance about effective learning strategies, and nearly all the teachers in our survey (97.1%) reported that they were keen to receive information about effective learning strategies. In addition, almost half (48. 5%) reported that they did not have access to relevant information on effective learning strategies.

The outcomes of this study provide important recommendations for how teachers in schools can improve the quality of advice and support offered to students on effective learning strategies. Teachers should highlight the following three points about learning strategies: (1) Which are the effective learning strategies and which are the less effective strategies?; (2) What are the benefits of using retrieval and spaced practice as learning strategies (i.e., how effective strategies promote learning)?; and (3) How does each strategy work (i.e., what are the practical ways to use effective strategies?)

Limitations

It is unfortunate that there was a typographical error on the wording of the response scale for the survey item assessing how often teachers promoted the common learning strategies (*survey item one*). Due to this error, we were unable to evaluate how frequently teachers promoted the learning strategies. By assessing how often teachers promote the learning strategies, it would have been possible to obtain a more valid indication of strategy recommendations. Despite the smaller sample size, this study achieved a response rate of 64.8%. However, the current survey focused exclusively on the subject leaders for science, future studies could usefully explore understanding and recommendations of learning strategies among both trainee science teachers and science teachers who are not the heads for science. A larger scale evaluation is needed on science teachers understanding and recommendation of learning strategies. We suggest further research whether with trainee, or science teachers who are not the heads for science should use more robust survey designs to help us obtain more generalisable findings and thereby, improve the quality of evidence we use for decision-making.

Chapter 3

Study 1: A Survey of Secondary School Students' Use and Understanding of Study and Revision Strategies for Science Examinations

Sultana, F., Watkins, C. R., Al Baghal, T., & Hughes, J. C (in prep). *A Survey of Secondary School Students' Use and Understanding of Study and Revision Strategies for Science Examinations.* Manuscript in preparation

Preface

By evaluating the existing literature on students' study practice (Chapter 1) we identified that most of the previous research studies used non-probability sampling methods (i.e., convenience sampling). There is currently a distinct lack of empirical research on secondary school students' use and understanding of evidence-informed learning strategies for independent learning. Previous studies on school students' study practice did not address students' understanding of learning strategies (i.e., knowledge of effective learning strategies, and what students understand to be the most- and least- effective strategies), or how schools support students to use learning strategies. Moreover, the generalisability of much published research on students' study practice is limited due to the sampling methodology employed by previous studies (i.e., convenience sampling). This led us to use more robust survey methodologies (i.e., probability sampling techniques) to select a random sample of learners aged 14–15 years olds studying in mainstream maintained secondary schools in North Wales.

This chapter contains two studies. Study 1 is a population based-survey in which we investigated use and understanding of evidence-informed learning strategies among secondary school students from a total of twenty-nine secondary schools in North Wales. In addition, we investigated the effort students' make towards independent learning (i.e., study and revision), and the support they receive from schools for study/revision. We conducted a cross-sectional survey using paper-based questionnaires. A multistage implicitly stratified sampling method was used for a sample selection. We present findings from a regionally representative sample of secondary school students in North Wales.

The second study is a survey evaluating the influence of the COVID-19 pandemic on secondary age students' independent learning practice that was commissioned by the Welsh Government. During the COVID-19 pandemic school closures, most students were required to complete schoolwork at home. Given the need for students to work independently, we wanted to evaluate whether students' independent learning practice might have changed. We conducted an online cross-sectional survey with students aged 14–15 and 16–17 years old attending secondary schools in Wales. For this survey, we employed a multistage clustered sample design for a sample selection. The findings were similar to our previous survey research with secondary students outlined in Study 1 of Chapter 3, and showed that students reported using both less and more effective learning strategies whilst learning at home.

Study 1 is the manuscript of the paper that we have prepared to submit for publication in the Journal of Research in Science Teaching. Study 2 is the full draft version of the report that we have submitted to Welsh Government. With the permission of Welsh Government we have the authority to share the second study in the current thesis (Appendix E).

Abstract

There is currently no population-based survey evaluating secondary school age students' use, or understanding of, learning strategies for independent study. There is also no research evaluating the effort students make towards independent study, nor how schools support students with study and/or revision strategies. In this paper we report data from a representative sample of 385 14-15 year old students from 29 secondary schools in the UK, using the Effective Revision and Study Strategies Questionnaire (ERaSSQ) survey. We conducted a cross-sectional survey using a multistage implicitly stratified sampling method. Our results show that the learning strategies most frequently used by students were making notes, repeatedly reading information, and highlighting or underlining information (i.e., less effective learning strategies). Our data also suggest many students do not have a complete understanding of the strategies that are known to be more effective. These results are of interest to secondary school teachers and education policymakers.

Keywords: retrieval practice; spaced practice; learning strategies; secondary school students; independent study and revision

Introduction

Using effective learning strategies in schools is an essential factor in improving educational outcomes for students. Existing research indicates that strategies such as retrieval and spaced practice are likely to be more effective in helping students achieve learning goals (Adesope, Trevisan & Sundararajan, 2017; Agarwal, Nunes & Blunt, 2021; Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; Karpicke & Aue, 2015; Roediger & Karpicke, 2006; Sotola & Crede, 2020). Despite the growing evidence supporting effective learning strategies, there remains a paucity of empirical research surrounding secondary school-aged students' use of learning strategies for independent study and/or revision. Prior research on school students' study practice has focused on the use of learning strategies, and there are currently no studies that have evaluated secondary school students' understanding of effective learning strategies, or how schools support students to use learning strategies (Agarwal, D'Antonio, Roediger, McDermott & McDaniel, 2014; Dirkx, Camp, Kester & Kirschner, 2019). There is also very little research that has reported on the effort students make towards independent study and revision (i.e., time spent studying and revising) (Agarwal et al., 2014; Oakes & Griffin, 2016).

The generalisability of much published research on students' study practice is hampered by the use of non-probability sampling methodologies (i.e., convenience sampling), and the present study aims to address this research gap by conducting a population-based survey with secondary school students. The primary aims of this study were to evaluate: (1) Which learning strategies do students use to study and/or revise in preparation for science examinations? and (2) What are students' understanding of some commonly used learning strategies? The secondary aims of this study were to identify: (1) How much time do secondary school students invest to study and revise independently to prepare for science examinations? and (2) Which learning strategies do school teachers encourage students to use for study/revision, and how schools support students to use these strategies? This survey was conducted in collaboration with the Regional School Effectiveness and Improvement Service for North Wales (GwE).

Learning strategies

Oakes and Griffin (2016) describe learning strategies as the activities students undertake for their independent work, in other words, *how* they go about learning key content and ideas on their own outside of the classroom without help from teachers. Examples of commonly used learning strategies include repeated reading approaches (i.e., repeatedly reading a core subject textbook or class book in order to understand and recall the content), completing retrieval practice activities (such as quizzes or attempting to answer previous exam papers), and making notes (e.g., key note taking, summarising text) (Dirkx et al., 2019; Karpicke, Butler & Roediger, 2009).

Over recent years there have been significant contributions to the research literature on learning strategies (Coe, Aloisi, Higgins & Major, 2014; Gorard & See, 2016; Moran & Malott, 2004; Rosenshine, 2012; Weinstein, Madan & Megan, 2018), several books and resources (Agarwal et al., 2014; Roediger, McDaniel & McDermott, 2020; Carey, 2015; Carpenter & Agarwal, 2020; Horvath, Lodge & Hattie, 2016), and a growing number of web-based and smartphone programmes (e.g., Quizlet [https://quizlet.com/en-gb], Kahoot [https://kahoot.com/] and Quizziz [https://quizizz.com/]). Several studies have shown that using effective learning strategies is related to improved outcomes in examinations, whereas the use of less effective strategies is related to poorer outcomes (Bartozewski & Gurung, 2015; Gurung, Weidert & Jeske, 2010; Hartwig & Dunlosky, 2011; Rodriquez, Rivas, Matsumura, Warschauer & Sato, 2018).

In an important review of the evidence on learning strategies, Dunlosky et al. (2013) evaluated ten commonly used learning strategies and arranged these into low, medium, and high utility categories based on how effective the strategies generalise across a range of key variables (e.g., learning conditions, student characteristics, materials and criterion tasks). Of these ten learning strategies, two strategies were identified as high utility (practice testing [note that we use the term retrieval practice here to include all activities involving the recall of information from memory] and distributed practice [note that we use the term spaced practice here]), three strategies were identified as having moderate utility (interleaved practice, elaborative interrogation and self-explanation), and five strategies were identified as having low utility (summarising, highlighting [or underlining], using keyword mnemonics, imagery use for text learning and repeatedly reading information).

Use and understanding of learning strategies

There is a lack of published research describing the use of learning strategies in mainstream educational settings by secondary age students (Agarwal et al., 2014; Dirkx et al., 2019). Previous studies are limited to surveys of undergraduate students, mainly in the social sciences, medicine, pharmacy and dentistry (Bartozewski & Gurung, 2015; Biwer, Egbrink, Aalten & de Bruin, 2020; Blasiman, Dunlosky & Rawson, 2017; Gurung et al., 2010; Hartwig & Dunlosky, 2011; Karpicke et al., 2009; Kornell & Bjork, 2007; McAndrew, Kamboj & Pierre, 2015; McAndrew, Morrow, Atiyeh & Pierre, 2016; Peña, Knecht & Gavaza, 2021; Piza, 2018; Rodriguez et al., 2018; Schmidmaier et al., 2011; Susser & McCabe, 2013; Morehead, Rhodes & DeLozier, 2016). These studies have consistently shown that undergraduate students' predominantly use less optimal learning strategies for independent study, such as repeated reading approaches and highlighting information during study, rather than using more effective strategies such as retrieval and/or spaced practice.

Agarwal et al.’s (2014) study of secondary school students showed that these learners also relied on less optimal strategies (i.e., repeated reading approaches), as opposed to more effective ones such as retrieval practice. However, it is worth noting that Agarwal et al.’s (2014) findings are based upon data collected from students at the end of an experimental study on learning strategies, and this may have influenced students’ responses.

More recently, a study by Dirkx et al. (2019) found that Dutch school students similarly relied on less optimal learning strategies (i.e., repeated reading approaches and making notes) compared to more effective learning strategies. Their study also revealed just over half of those surveyed ranked repeatedly reading information as their primary learning strategy (51.1%), in contrast a very low proportion ranked retrieval practice as their primary learning strategy (8.1%). However, the Dirkx et al. (2019) study did not report students’ understanding of various learning strategies.

Barriers to the optimal use of evidence-informed learning strategies by students for independent work include factors related to student understanding of learning strategies, effort toward independent work and recommendations from educators (Biwer et al., 2020; Blasiman et al., 2017; Hartwig & Dunlosky, 2011; Kornell & Bjork, 2007; McCabe, 2011; Morehead et al., 2016; Peña et al., 2021; Susser & McCabe, 2013).

Studies in university settings have shown that undergraduate students have limited knowledge of effective learning strategies and they primarily use retrieval practice as a diagnostic tool to evaluate their learning, rather than as a method to actually *learn* information (Hartwig & Dunlosky, 2012; Kornell & Bjork, 2007; Kornell & Son, 2009; McAndrew et al., 2016; McCabe, 2011; Morehead et al., 2016; Piza, 2018; Schmidmaier et al., 2011). Recently, Blasiman et al. (2017), asked university students to rate the effectiveness of various learning strategies, and found that less optimal learning strategies were rated as effective by the highest proportion of students (i.e., reading and highlighting notes). To date there has not been any comparable research undertaken with secondary school students.

There is a lack of published research describing the effort secondary school-aged students make towards independent study and/or revision in schools (Agarwal et al., 2014). In recent studies evaluating barriers to the use of effective learning strategies in university settings, students' reported that using effective learning strategies required time and effort (Biwer et al., 2020; Peña et al., 2021). Despite the significance of investing time and effort to maximise the impact of using more effective learning strategies, there remains a paucity of evidence on the effort secondary school-aged students make towards independent study and revision (Oakes & Griffin, 2016). This study aims to update our knowledge on how much independent study school students undertake.

School teachers are an important source of information and guidance for students as they prepare to learn and revise for examinations. Studies showed that university instructors promote both less and more effective learning strategies, and have a moderate understanding about evidence-informed learning strategies (McCabe, 2018; Piza, 2018; Morehead et al., 2016). Previous published research on instructors' recommendations and understanding of learning strategies is limited to surveys of higher education instructors and there remains an absence of research evaluating the strategies teachers most commonly promote in schools (McCabe, 2018; Piza, 2018; Morehead et al., 2016). The current study aims to close this knowledge gap.

The current study also uses a sampling method that differs significantly from that of earlier studies. Previous research predominantly used non-probability sampling methods (i.e., convenience sampling), and therefore did not include a random sample of learners. A limitation of this approach is that the results from previous studies are likely to be biased towards over- or under-reporting of students who were more- or less interested and therefore more or less likely to volunteer to take part in the survey based on their interest in improving their study and/or revision practice. In this study, we used a random probability sampling method (i.e., multistage implicitly stratified sampling) to obtain a random sample of learners. As our student sample included a stratified random sample of students following different science qualifications, our results are less likely to be distorted due to chance under-representation of students who were less academically able and were following a science qualification that made up a smaller proportion of the student population.

Previous research has often failed to ask learners about their use of learning strategies for a specific subject or exam (see Agarwal et al., 2014 for an exception, although these findings are based on data collected from students at the end of an experimental study on retrieval practice). Therefore, in this study we specifically designed the survey items to measure students' study practice as they work towards the General Certificate in Secondary Education (GCSE) science award. In Wales, United Kingdom, students begin studying towards the General Certificate in Secondary Education (GCSE) in Year 10 (aged 14-15 years). Students follow a 2-year programme of study for each GCSE subject, and there are four compulsory subjects for all learners (English, Welsh, mathematics and science). Learner progress is assessed through a combination of examinations, coursework and teacher assessment. Importantly, the GCSE qualifications students achieve play a significant role in determining their future academic and career paths, and are highly valued by schools, colleges, universities and employers. We focused on secondary school students in the 14-15 age groups as that was a key school improvement priority for our partners in the Regional School Effectiveness and Improvement Service for North Wales (GwE).

Although the current study focused on students aged 14-15 years in secondary schools in North Wales, schools in other nations across the UK follow very similar GCSE curricula and organisational structure. Therefore, the results from this study are likely to generalise to learner populations of this age across the UK. Research into students' study practice that focuses exclusively on the UK education system is limited. If secondary school students use less effective learning strategies, it is important to intervene at the earliest opportunity to provide learners with knowledge of more effective strategies that they can use as they progress through education and training. Gathering reliable information on the strategies students' use to study for GCSE science subjects can provide important information to help schools improve the quality of the advice they provide learners. This information will also be invaluable for school improvement professionals and providers of teacher initial education.

Methods

The target population for the current survey was defined as school students aged between 14 and 15 years studying external GCSE science qualifications in mainstream secondary schools in North Wales, United Kingdom. We calculated a sample size of 924 school students aged between 14 and 15 years following statistical guidelines in the Sampling and Sample Size Calculation guide produced by the National Institute for Health Research Research Design Service (Fox, Hunn & Mathers, 2007), as well as advice from a survey statistician. We planned our sample size on a student population of 6,900, with a desired precision of 0.03, and using the most conservative assumed element variance with a 95% confidence interval. We conducted a cross-sectional survey using a multistage implicitly stratified sampling method between April 2019 and July 2019 using paper-based questionnaires. At the first stage of the sampling process, we invited all 54 mainstream maintained secondary schools in the six local authorities in North Wales (Anglesey, Gwynedd, Conwy, Denbighshire, Flintshire and Wrexham), to participate in the survey. This ensured all schools in the region, irrespective of size, language category and geographical location, were invited to participate. Twenty-nine schools agreed to take part.

The inclusion criteria for school students were (1) students aged between 14 and 15 years (school Year 10); and (2) students studying either triple GCSE science award, double GCSE science award and BTEC and/or applied science awards. The first author randomly selected a sample of students proportionate to the total number of students in the Year 10 cohort from an anonymised list of students provided by each school. To ensure that the sample of students represented different ability levels, we used an anonymised list of Year 10 students sorted according to the science qualification they were studying (e.g., all students studying triple GCSE science were listed first, followed by all students studying double GCSE science and then all students studying BTEC and/or applied GCSE science). The science qualification information was then used as an indicator of students' academic ability in school science (i.e., more academically able students typically follow the triple science award, with the remaining students generally following the double science and BTEC and/or applied science qualifications). Every *n*th student was then selected on the list (after a random starting point was generated). This allowed every eligible school student an equal chance of selection and allowed representation of each ability level in the final sample for each school in its correct proportion.

Study information and consent letters were forwarded to the parents and carers. This informed parents and carers about their child's participation in the study and provided the option to withdraw them from the survey. We obtained ethical approval for this study from the Research Ethics Committee of Bangor University (ethical approval number: 2018-16316).

Survey procedure

We developed the Effective Revision and Study Strategies Questionnaire (ERaSSQ) survey using *Online Surveys* programme (https://www.onlinesurveys.ac.uk/). All students completed the ERaSSQ (Appendix A) in school under the supervision of the first author (or an independent data collector) and a member of the school staff.

We provided both a verbal and written introduction to the research study and survey, and explained how the survey could be completed in Welsh or English. We emphasised that students’ answers would be treated with confidentiality, that there were no ‘right’ or ‘wrong’ answers, and that their responses would not reflect on their current science performance or their school. The students were then given the opportunity to consider their participation in the survey, opt-out or provide assent prior to completing the questionnaire. The printed questionnaires were completed by students on their own in a quiet room (one student received assistance from a learning support teaching assistant). Completion of the survey questionnaire was self-paced and the session took approximately 30 minutes. Students were thanked for their assistance and given a debrief about the study. Neither students nor schools were remunerated for their participation in the survey.

Survey measure development

We developed the ERaSSQ survey to assess the study habits of secondary school students. To inform the development of the survey items, key aspects of students’ study and revision practices were identified following a review of the literature (Blasiman et al., 2017; Dunlosky et al., 2013; Kornell & Bjork, 2007; Oakes & Griffin, 2016). These included the use and understanding of common learning strategies, effort towards independent learning, and school-based support with study/revision. Existing instruments for assessing students’ use of learning strategies such as the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich et al., 1991) do not include the learning strategies recently evaluated by Dunlosky et al. (2013) or questions on students’ understanding of learning strategies. In this study, therefore, we developed new survey items to measure students’ use and understanding of these common learning strategies that were informed by previous survey research on students' study practice (Blasiman et al., 2017; Dunlosky et al., 2013; Karpicke et al., 2009; Kornell & Bjork, 2007). The survey items on effort towards independent study were informed by Oakes and Griffin (2016).

Use and understanding of learning strategies. To measure students' use of learning strategies, we asked students to rate how often they used nine common learning strategies on a 5-point scale from never (1) to always (5) (see *item 1,* Appendix A). The nine learning strategies are presented in Table 3.1. The students also had the option to list a learning strategy(ies) that was not mentioned in the list (see *item 2*). We then asked the students to write down the three learning strategies they most frequently used from the nine listed strategies, and rate how helpful the three learning strategies are on a 5-point Likert scale from not at all helpful (1) to extremely helpful (5) (see *item 3*).

To measure students' use of learning strategies for the three different science subjects (biology, chemistry and physics), we asked students if they used any of the nine listed strategies to study/revise for these three subjects (see *item 6*). To measure students' understanding of the benefit of retrieval practice, spacing, using flashcards and mind maps as learning strategies, we asked students to choose one option that indicated why they would use each strategy to prepare for an upcoming science exam (adapted from Kornell & Bjork, 2007) (see *items 9 to 12*).

Support with study/revision. To measure which learning strategies teachers most commonly promote in schools, we asked students if their current science teacher(s) had encouraged them to use any of the nine learning strategies to study/revise for science (see *item 4*). The students also had the option to list a learning strategy(ies) that was not mentioned in the list (see *item 5*). To evaluate whether there is a need to provide additional information and support on the use of evidence-informed learning strategies in secondary schools, we asked whether schools offer students assistance with study/revision skills for science and if they were interested in learning about evidence-informed learning strategies to help them study/revise effectively *(*see *items 14 to 16).*

Effort towards independent study and revision. To measure effort towards independent study, we asked students how many hours of study they do for science outside of science lessons in a typical week (see *item 7*). To measure effort towards revision, we asked students how many hours of revision they do in the weeks leading up to a science exam (see *item 8*). These questions were informed by Oakes and Griffin (2016).

Table 3. 1 *Overview of commonly used learning strategies evaluated in the ERaSSQ survey*[a]

Learning strategy		
Terms used in present study	Terms used by Dunlosky et al. (2013)	Description
Highlighting or underlining information	Highlighting/underlining	Marking, underlining important information
Repeatedly reading information	Rereading	Reading information over and over
Making notes (summarising)	Summarisation	Writing notes/summaries (of various lengths)
Spaced practice	Distributed practice	Spreading study/revision sessions over time

Learning strategy		
Terms used in present study	Terms used by Dunlosky et al. (2013)	Description
Doing practice tests	Practice testing	(i.e., retrieval practice) Retrieving information from memory by completing practice tests (e.g., past papers)
Interleaved practice	Interleaved practice	Mixing study of different, related topics, concepts or problems
Elaborate encoding		Connecting what you are trying to learn to what you already know (e.g., using mnemonics). Making connections between information to be learned and other information.
Using mind maps[b]		Writing down a key topic, and from this creating links composed of keywords, phrases, concepts, facts and figures. Mind maps are typically presented as diagrams.
Using flashcards[c]		Writing key terms, facts or to be learned information on small cards. Flashcards are typically two-sided with the prompt / question appearing on one side and the information about the prompt / answer on the other).

Note. [a]The ERaSSQ assessed the use of seven strategies evaluated by Dunlosky et al. (2013). In the present study, two additional learning strategies identified in the literature on student study habits were also included (*using flashcards* and *using mind maps*). [b,c]Neither of these strategies were recognised in the review by Dunlosky et al. (2013). [b]Using flashcards and doing practice tests can be used as retrieval practice activities. However, in the present study, we analysed using flashcards and doing practice tests separately.

Pilot study

We piloted the ERaSSQ on a convenience sample of 535 students (aged 14 to 17 years) attending five secondary schools in North Wales between June 2018 and July 2018. To assess student understanding of the ERaSSQ survey, we also asked students to complete respondent debrief forms immediately after completing the ERaSSQ survey. The debrief forms included open-ended questions to measure students' comprehension of the survey questions and learning strategies. In the questions in the debrief forms, we asked students to paraphrase the survey questions. Overall, students communicated that they understood the content of the survey questions, and their feedback was used to improve the clarity of the language for less able readers. Revised versions of the English and Welsh surveys were proofread by an experienced science examiner.

Statistical analysis

Although this survey design included equal selection probabilities, not all sampled units (i.e., schools and students) were observed. To attempt to more appropriately represent all 14-15 year old students studying in mainstream maintained secondary schools in North Wales, we made several weighting adjustments to compensate for survey non-response, coverage errors and aligning the population proportions. The final weighting variable in this dataset is a multiplication of: (1) school design weight; (2) school non-response weight; (3) student design weight; and, (4) and post-stratification weights.

The school design weight is 1 for all schools given the take-all design. To calculate the school non-response weight, we conducted a logistic regression analysis model to estimate the probability of school response based on variables known for responding and non-responding schools. These include: (1) the 2018/19 national school categorisation system for Wales was used as a proxy for school effectiveness (Welsh Government, 2020); (2) the percentage of students in Year 10 eligible for free school meals (eFSM) for 2018/19; (2) school GCSE science attainment scores for Year 10 in 2018/19; and (4) school attendance of students in Year 10 for 2018/19. The logistic regression model results (i.e., propensity scores for responding and non-responding schools) are presented in Table C.1 (see Appendix C). These school data were provided by the Regional School Effectiveness and Improvement Service for North Wales (GwE). The school weight is the inverse of the estimated probability values (i.e., 1 divided by the estimated response probability for each school).

The survey design we employed ensured equal student selection probabilities and are equivalent to the ratio of the number sampled within a school (ni) to the population size of the school (Ni). The design is such that the sample selected is proportionate to the school size, and hence equal across all students within school. In this instance for all students ni/Ni~=0.134, and the design weight for all students is the inverse of this number. We weighted student data to use post-stratification techniques, as the number of variables to build a non-response model was limited to only one (science award) which was available for responding and non-responding students. For post-stratification, our aim was to weight the observed data (i.e., from respondents) to known totals of the population. There were two variables available: student gender and science award. The population data on student science awards was obtained from the sample frame, and the data on student gender was obtained from the Welsh Government Pupil Level Annual School Census (PLASC) data for 2019 (Statistics for Wales, 2019). However, there was missing data for some respondents for gender (5.7%). To use the post-stratification techniques, we first imputed gender on these missing cases using hot-deck methods (Andridge & Little, 2010). Missing cases were replaced by values of similar cases within the science award categories based on responses to survey items four through six. We then used iterative proportional fitting (IPF) to estimate the post-stratification weights to these two marginal proportions (Kolenikov, 2014). The final survey weight is then a multiplication of the several weighting adjustments, which compensated for the survey design, unit non-response and aligning population proportions.

The item response rate for each survey item in the present study was greater than 95.0% and, therefore, no further steps were taken to assess potential item non-response bias (Pazzaglia, Stafford, & Rodriguez, 2016). Any missing data was handled using pairwise deletion. The development of the survey weights was performed using the statistical software functions in R and STATA (version 15). Due to the complex sample design (i.e., multistage), we analysed the data using SPSS Complex Samples (version 25), which incorporates the weighting variable as well as the survey design into survey analysis. In addition, we also used the ‘survey’ package in R for analysing data from complex surveys, to analyse survey item three.

Analysis of open-ended responses

In addition to the nine learning strategies listed in the ERaSSQ survey, we gave students the opportunity to report any additional learning strategy(ies) they used. The first author evaluated all responses to the open-ended questions and constructed separate categories for responses that were not one of the nine learning strategies listed in the survey. Although some of the students’ responses were considered to be examples of one of the nine listed strategies (e.g., making notes, retrieval practice), we constructed separate categories for all the open-ended responses as this provided valuable information on how students adapt strategies, and on students’ understanding of learning strategies. The new categories were: (1) making notes; (2) using learning resources; (3) using learning resources to complete retrieval practice activities; (4) watching and/or listening to learning resources; (5) completing other retrieval practice activities; (6) teaching and/or studying with others; and (7) undertaking other activities (i.e., one of the nine listed learning strategies that was used differently). The second author then undertook an independent review of the responses and categories. Agreement was assessed and any discrepancies discussed. The first author then classified all the open-ended responses into the seven categories.

Results

Response rates

Twenty-nine secondary schools in North Wales, United Kingdom participated in the survey. This represents a response rate of 53.7%. The response from selected students in participating schools was 74.8%, generating 385 completed questionnaires. Table 3.2 presents the characteristics of the participating schools and Table 3.3 presents the characteristics of the participating students.

Table 3. 2 *Characteristics of the participating secondary schools*

		Participating schools
	Variable	*n*
Location (i.e., local authority)	Anglesey	4
	Gwynedd	9
	Conwy	2
	Denbighshire	3

		Participating schools
	Variable	*n*
	Flintshire	7
	Wrexham	4
Language category of school	Bilingual (Type A)*	7
	Bilingual (Type B)**	3
	English medium	12
	English with significant Welsh	2
	Welsh medium	4
School size	Small[a]	14
	Medium-sized[b]	9
	Large[c]	6
School eFSM percentage[d]	Up to 8 per cent	8
	Over 8 per cent and up to 16 per cent	15

		Participating schools
	Variable	*n*
	Over 16 per cent and up to 24 per cent	5
	Over 24 per cent and up to 32 per cent	1
	Over 32 per cent	

Note. [a]Small refers to secondary schools with 600 students or fewer. [b]Medium-sized refers to schools with between 601, and 1,100 students. [c]Large refers to schools with 1,101 or more students. Definitions of school sizes were adopted from the Estyn report on school size and educational effectiveness (2013). eFSM represents students eligible for free school meals. [d]School eFSM percentage refers to the mean percentage from the last three years. *Bilingual Type A are Welsh medium secondary schools / middle schools where at least 80% of the subjects apart from English and Welsh are taught only through the medium of Welsh to all pupils. One or two subjects are taught to some pupils in English or in both languages. **Bilingual Type B are Welsh medium secondary schools / middle schools where at least 80% of the subjects (excluding Welsh and English) are taught through the medium of Welsh but are also taught through the medium of English. Definitions of school Welsh medium type were adopted from the school data obtained from Statistics for Wales.

Table 3. 3 *Characteristics of the participating secondary school student respondents*

		Participating students	
	Variable	*n*	%
Gender	Male	199	50.9
	Female	167	43.4

		Participating students	
	Variable	*n*	%
	Other	4	1.0
	Prefer not to say	13	3.4
GCSE/BTEC science award	GCSE triple science	75	19.5
	GCSE double science	299	77.7
	BTEC and/or GCSE applied science	11	2.9
Location (i.e., local authority)	Anglesey	51	13.2
	Gwynedd	80	20.8
	Conwy	36	9.4
	Denbighshire	49	12.7
	Flintshire	106	27.5
	Wrexham	63	16.4

Which learning strategies do secondary school students most commonly use?

The primary aim of this survey was to evaluate which learning strategies secondary school students' use to study and/or revise to prepare for their science examinations. We asked students to indicate how often they used the nine common learning strategies to study/revise for science. Table 3.4 shows the nine learning strategies, and the mean weighted scores ranked from highest to lowest by their reported average frequency of use (with higher values indicating higher frequency of use). The percentages of students reporting the various frequencies per learning strategy are presented in Table D.1 (see Appendix D).

Table 3. 4 *Weighted mean scores for student responses to the survey question, "How often do you use the following learning strategies when you study/revise for science?" (Survey Item 1)*

Learning strategy	$\bar{x}$	*SE*
Making notes (summarising)	3.8	0.1
Repeatedly reading information	3.8	0.1
Highlighting or underlining information	3.5	0.1
Doing practice tests[a]	3.2	0.1
Spaced practice	3.1	0.7
Using mind maps	2.8	0.1
Using flashcards	2.7	0.1

Learning strategy	$\bar{x}$	*SE*
Elaborate encoding	2.3	0.1
Interleaved practice	2.0	0.1

Note. Learning strategies are arranged from most to least often used, based on mean weighted scores. Student ratings of how often they used the nine learning strategies were made on a 5-point scale, from never (1) to always (5). Higher ratings indicate higher frequency of use. [a]In the present study, we used term *practice tests* to refer to retrieval practice in the ERaSSQ survey.

The qualitative data from the free response question about students' use of additional learning strategy(ies) were classified into seven broad categories, and the percentage of students with a response in each category was computed. Two of the responses could not be categorised. Some students mentioned more than one additional learning strategy, which fitted into multiple other categories. The categories were: (1) making notes; (2) using learning resources; (3) using learning resources to complete retrieval practice activities; (4) watching and/or listening to learning resources; (5) completing other retrieval practice activities; (6) teaching and/or studying with others; and, (7) undertaking other activities (one of the nine listed learning strategies that was used differently). A description of the seven categories, as well as examples from each category, alongside respondent's characteristics, is presented in Table 3.5.

Table 3. 5 *Students' reports of use of additional learning strategies (Survey Item 2)*

Category	Description	% (n)	Example
Making notes	Making notes using posters, post-it notes, diagrams, mind maps, and/or using other note taking approaches	23.8 (34)	Watch and make notes on videos from GCSEPod (General Certificate of Secondary Education) (female, following GCSE triple science award). I make revision posters and put them up in my bedroom so I see them often (female, following GCSE double science award). Vibrant notes across the walls of my room (female, following GCSE double science award).
Using learning resources	Using web-based and/or smartphone learning resources (e.g., Bitesize[a], GCSEPod[b] WJEC[c] (Welsh Joint Education committee), Tanio.cymru[d] Isaac Physics[e]) or hard copy learning resources (such as revision guides) without specifying how these learning resources were used to learn the content	18.2 (26)	Website e.g., Bitesize, Tanio.cymru (female, following GCSE triple science award). Using Bitesize (female, following GCSE triple science award). Go online on (Tanio.cymru) and learn from that (male, following GCSE double science award).
Using learning resources to complete retrieval	Using web-based and/or smartphone learning resources to complete retrieval practice activities (e.g., completing tests/quizzes on	7.7 (11)	Use online tests like WJEC (male, following GCSE triple science award). Take quizzes online or on science revision apps (female, following GCSE double science award).

Category	Description	% (n)	Example
practice activities	Bitesize[a], WJEC[c], Quizziz[f] , Tanio.cymru[d], Kahoot[g]).		Online quizzes, Bitesize (female, following GCSE triple science award).
Watching and/or listening to learning resources	Watching and/or listening to learning resources (e.g., on YouTube[h], GCSEPod[b], Bitesize[a], Tanio.cymru[d] website or content developed by students).	18.9 (27)	Watch science videos on YouTube (female, following GCSE triple science award). Watch science revision on Twig/YouTube (male, following GCSE double science award). Online videos and online presentations from Tanio.Cymru (male, following GCSE double science award). Making songs and voice notes and repeatedly listen to it (female, following GCSE double science award).

Category	Description	% (n)	Example
Completing other retrieval practice activities	Completing other retrieval practice activities (i.e., any activity involving recall of information from memory). For example, being tested by others, completing quizzes, completing cloze text activities, and writing their own questions.	15.4 (22)	My friend goes through every topic asking a variety of questions that he makes on the spot. Once he reached the end of topics. I then go through the same process with him. This usually takes 2 hours (male, following GCSE triple science award). Getting a family member to test me (female, following GCSE triple science award). By having my friends ask me questions (female, following GCSE double science award). Short quick fired questions (female, following GCSE double science award).
Teaching and/or studying with others	Teaching others and/or studying with others (e.g., friends, family, study groups).	4.2 (6)	Dysgy y gwybodaeth i person arall / teaching the information to another person (male, following GCSE triple science award). Gael rhywyn ddarllen allan i mi / have someone else read out to me (male, following GCSE double science award). Explaining/telling other people about the work (female, following GCSE triple science award).

Category	Description	% (n)	Example
Undertaking other activities (one of the nine listed learning strategies)	Using one of the common learning strategies assessed in this study differently (i.e., highlighting and/or underlining information or notes, reading information or notes, spaced practice, elaborate encoding).	11.9 (17)	Reading revision books (male, following GCSE double science award). Aroleuno pethau pwysig / highlighting important things (female, following GCSE double science).

Note. [a] Bitesize [https://www.bbc.co.uk/bitesize], [b] GCSE Pod [https://www.gcsepod.com/], [c]WJEC [https://www.wjec.co.uk/], [d]Tanio Cymru [http://tanio.cymru/], [e]Isaac Physics [https://isaacphysics.org/], [f]Quizziz [https://quizizz.com/], [g]Kahoot [https://kahoot.com/], [h]YouTube [https://www.youtube.com/]

Students' ratings of the effectiveness of the most frequently used learning strategies.

We also aimed to evaluate students' beliefs on the effectiveness of the learning strategies they most frequently use. Table 3.6 shows the nine learning strategies, the weighted percentages of students who reported using the learning strategies, arranged from most to least frequently used, and students' ratings of the perceived efficacy of the learning strategies they most often used (higher mean weighted scores indicated that the students rated the strategy as more effective).

Table 3. 6 *Weighted percentage scores for students' use of the common learning strategies, and the weighted mean scores for students' ratings of how helpful they are (Survey Item 3)*

Learning strategy	%	$\bar{x}$	*SE*
Making notes (summarising)	20.6	4.0	0.1

Learning strategy	%	$\bar{x}$	*SE*
Repeatedly reading information	16.0	3.7	0.19
Highlighting or underlining information	14.9	3.7	0.1
Using mind maps	14.6	3.6	0.1
Doing practice tests[a]	14.0	3.9	0.1
Using flashcards	12.2	3.9	0.1
Spaced practice	3.8	3.7	0.2
Elaborate encoding	2.3	3.8	0.2
Interleaved practice	1.7	3.0	0.4

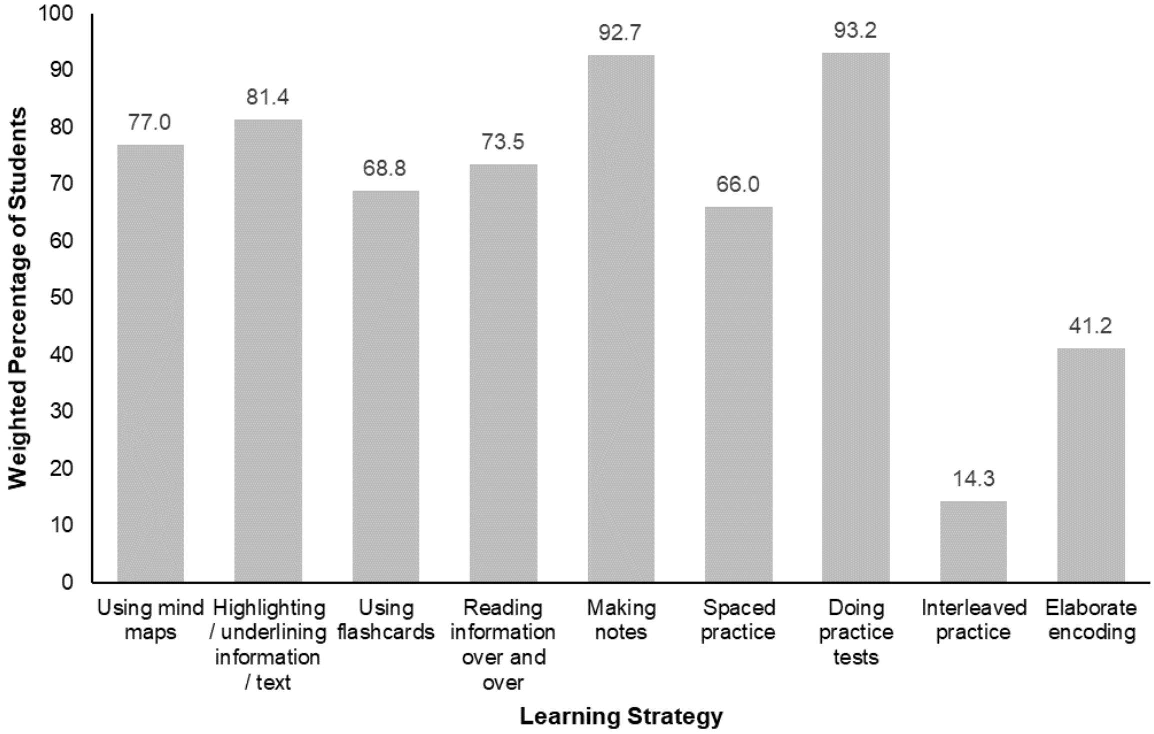
Note. Proportions are based on the three learning strategies students reported most frequently using. Student ratings of how effective they believed the three strategies they most commonly used were made on a 5-point scale, from not at all helpful (1) to extremely helpful (5). Higher ratings indicate that the students rated the strategy as more effective. [a]In the present study, we used term *practice tests* to refer to retrieval practice in the ERaSSQ survey.

Which learning strategies are students encouraged to use by secondary school teachers?

The secondary aim of this survey was to identify how schools support students with study/revision. To measure which learning strategies students are being encouraged to use by science teachers in secondary schools, we asked the students whether their current science teacher(s) had encouraged them to use any of the nine common learning strategies. Figure 3.1

shows the weighted percentages of students reporting whether they were encouraged to use any of the nine learning strategies.

Figure 3. 1 *Weighted percentage scores for student responses to the survey question, "Have any of your current science teacher(s) encouraged you to use any of the following learning strategies when you study/revise for science?" (Survey Item 4)*



The qualitative data from the free response-question about any additional learning strategy(ies) the students reported being encouraged to use by their current science teachers were also classified into seven broad categories. The new categories were: (1) to use learning resources; (2) to use learning resources to complete retrieval practice activities; (3) to watch and/or listen to learning resources; (4) to use other retrieval practice activities; (5) to make notes; (6) to teach and/or study with others; and, (7) to use other activities (i.e., one of the nine listed learning strategies that was used differently). A description of the seven categories, as well as examples from each category, alongside respondent's characteristics, is presented below in Table 3.7.

Table 3. 7 *Students' reports of the use additional learning strategies as encouraged by their school teacher(s) (Survey Item 5)*

Category	Description	% (n)	Example
To use learning resources	To use of web-based and/or smartphone learning resources (e.g., Bitesize[a], GCSEPod[b], WJEC[c], Tanio.cymru[d], Isaac physics) or physical learning resources (such a revision guides), without specifying *how* their teacher might have encouraged students to use these learning resources to learn the scientific content.	33.3 (25)	GCSEPod/Tanio.cymru website (male, following GCSE triple science award). Online resources e.g., GCSEPod (female, following GCSE double science award). Defnyddio y we, Tanio.cymru / Use the Tanio.cymru website (female, following double GCSE science award). Use a revision website called Tanio.cymru to revise for science (female, following GCSE double science award). Usually encouraged to use websites such as Bitesize (male, following GCSE double science award).
To use learning resources to complete retrieval practice activities	To use of web-based and/or smartphone learning resources to complete retrieval practice activities (e.g., completing tests/quizzes on Bitesize[a], Quizziz[e], Tanio.cymru[d], Kahoot[f], or answering past papers questions using WJEC.	13.3 (10)	Using a good website which tests you (female, following GCSE double science award). Take quizzes on science revision apps (female, following GCSE double science award). Use revision guides, answer test questions (female, following GCSE double science award).

Category	Description	% (n)	Example
To watch and/or listen to learning resources	To watch and/or listen to learning resources (e.g., on YouTube, GCSEPod, Bitesize, Tanio.cymru website).	13.3 (10)	Watch video clips online from Cbac (WJEC) and Bitesize websites (male, following GCSE double science award). The use of GCSEPod, Tanio.cymru, watching videos about the subject (female, following GCSE triple science award). Defnyddio clipiau fidio, Tanio.cymru / Use video clips, Tanio.cymru (female, following GCSE double science award).
To use other retrieval practice activities	To complete other retrieval practice activities (i.e., any activity involving recall of information from memory). For example, being tested by others, completing quizzes, completing cloze text activities and writing their own questions.	17.3 (13)	Question and answer. Give your parents some questions to ask and answer (male, following GCSE triple science award). Making questions, doing quick questions and answering them (female, following GCSE double science award). Recalling all the information we know on a topic and writing it on to a piece of paper and then going through our notes to check its right (female, following GCSE double science award). Recall strategy, write down what you know in two minutes and then check to see if it’s right (female, following GCSE double science award).

Category	Description	% (n)	Example
To make notes	To make notes using posters, post-it notes, diagrams, mind maps and/or using other note taking approaches.	10.7 (8)	Using diagrams and labelling them (male, following GCSE double science award). Encouraged to make bright and colourful posters (preferred not to say gender, following GCSE double science award). Draw a huge circle and add sectors and in the sectors write information of each topic (female, following GCSE double science award). Revision posters, post-it notes (female, following GCSE double science award).
To teach and/or study with others	To teach others and/or study with others (e.g., friends, family, study/revision sessions or groups) to learn and/or revise science knowledge	4.0 (3)	Revising by helping another to understand a subject (male, following GCSE triple science award). Revision sessions in school (female, following GCSE double science award). Drop in session. Hot seat (female, studying GSCE double science award).

Category	Description	% (n)	Example
To use other activities	To use one of the common learning strategies assessed in this study differently (i.e., highlighting and/or underlining information or notes, reading information or notes, spaced practice, elaborate encoding).	8.0 (6)	Reading the information out loud (female, following GCSE double science award). Uwcholeou geiriau pwysig / highlighting important words (female, following GCSE double science award). Looking through your books (female, following GCSE double award).

Note. [a] Bitesize [https://www.bbc.co.uk/bitesize], [b] GCSE Pod [https://www.gcsepod.com/], [c]WJEC [https://www.wjec.co.uk/], [d]Tanio Cymru [http://tanio.cymru/], [e]Isaac Physics [https://isaacphysics.org/], [f]Quizziz [https://quizizz.com/], [g]Kahoot [https://kahoot.com/], [h]YouTube [https://www.youtube.com/]

Which learning strategies do students' use for the three science subjects (i.e., biology, chemistry and physics)?

To measure which learning strategies students' used to study/revise for each of the three science subjects (biology, chemistry and physics) on their own outside of science lessons, we asked students to indicate using a 'yes' or 'no' response option against each strategy. Table 3.8 shows the nine learning strategies, and the weighted percentages of students who reported using the learning strategies for each science subject.

Table 3. 8 *Weighted percentage scores for student responses to the survey question, "Which of the following learning strategies do you use to study/revise for the three science subjects?" (Survey Item 6)*

Learning strategy	Biology	Chemistry	Physics	Biology and chemistry	Biology, chemistry and physics	Chemistry and physics	Biology and physics	None of the sciences
	% (SE)	*% (SE)*	*% (SE)*	*% (SE)*	*% (SE)*	*% (SE)*	*% (SE)*	*% (SE)*
Using mind maps	14.9 (1.8)	5.5 (1.7)	5.8 (1.5)	6.7 (1.4)	36.0 (3.3)	1.5 (0.6)	7.3 (1.7)	22.2 (2.7)
Highlighting or underlining information	7.7 (1.3)	5.7 (1.2)	4.1 (1.0)	7.6 (1.7)	54.8 (3.0)	5.6 (1.3)	3.1 (1.0)	11.4 (2.1)
Using flashcards	11.0 (1.7)	7.5 (1.7)	6.4 (1.2)	5.4 (1.3)	32.0 (4.3)	2.3 (0.9)	3.7 (0.9)	31.8 (3.5)
Repeatedly reading information	6.8 (1.3)	4.9 (1.1)	4.1 (1.0)	4.7 (1.5)	63.3 (3.0)	4.2 (1.1)	3.4 (1.1)	8.6 (1.3)
Making notes (summarising)	4.0 (0.9)	5.1 (1.1)	5.8 (1.2)	4.2 (1.3)	66.8 (2.6)	3.0 (0.8)	4.0 (1.0)	7.2 (1.4)

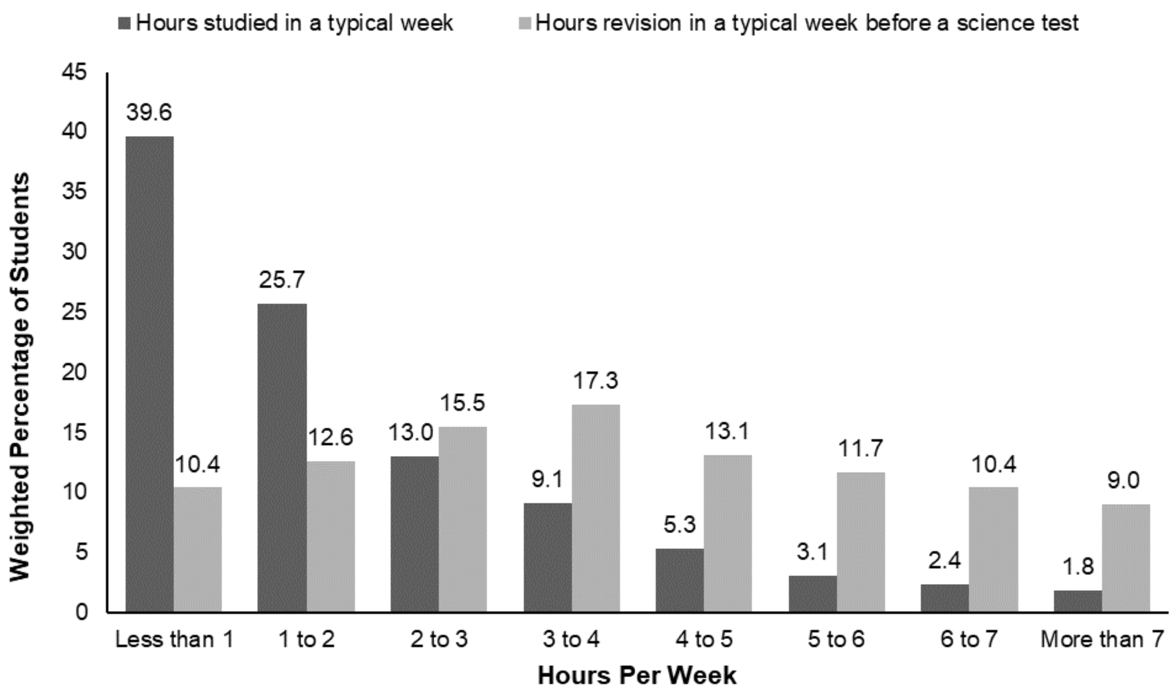
Learning strategy	Biology	Chemistry	Physics	Biology and chemistry	Biology, chemistry and physics	Chemistry and physics	Biology and physics	None of the sciences
	% (SE)	*% (SE)*	*% (SE)*	*% (SE)*	*% (SE)*	*% (SE)*	*% (SE)*	*% (SE)*
Spaced practice	6.6 (1.3)	7.6 (1.7)	5.6 (1.1)	5.1 (1.6)	37.7 (2.5)	4.3 (1.0)	2.8 (1.0)	30.4 (2.3)
Doing practice tests[a]	5.6 (1.6)	5.8 (1.6)	4.3 (0.9)	4.8 (1.0)	61.7 (3.4)	5.2 (1.0)	4.2 (1.1)	8.4 (1.8)
Interleaved practice	4.2 (1.2)	5.3 (1.4)	2.8 (0.8)	5.6 (1.3)	13.3 (1.6)	4.1 (0.9)	1.8 (0.6)	63.0 (2.5)
Elaborate encoding	11.7 (2.5)	7.4 (1.5)	12.0 (1.7)	3.7 (1.0)	12.0 (1.9)	2.7 (0.9)	5.8 (2.1)	44.7 (3.8)

Note. [a]In the present study, we used term *practice tests* to refer to retrieval practice in the ERaSSQ survey.

How much effort do students' invest to study and revise on their own (i.e., time spent studying and revising)?

In this survey, we also aimed to identify how much effort (i.e., time) do secondary students' invest to study and revise in preparation for science examinations. To measure how much time secondary students' invest to study and revise for science on their own outside of science lessons, we asked students to indicate how much time they spent studying in a typical week for science outside of lessons. Next, we asked students to indicate how much time they spent revising in the weeks leading up to a science exam. Figure 3.2 shows the weighted percentages of students reporting the various number of hours of study, and the number of hours of revision.

Figure 3. 2 *Weighted percentage scores for student responses to the survey questions, "In a typical week how many hours of study do you do for science outside of lessons" and, "In the weeks leading up to a science test how many hours do you revise in preparation outside of lessons?" (Survey Items 7 and 8)*



Students' understanding of the benefit of retrieval practice, spaced practice, flashcards and mind maps.

In this survey we also aimed to evaluate students' understanding of how helpful some learning strategies are. Table 3.9 shows the weighted percentages of students' understanding of the benefit of retrieval practice, spaced practice, using mind maps and using flashcards.

Table 3. 9 *Weighted percentage scores for understanding of the benefit for using retrieval practice, spaced practice, flashcards and mind maps (Survey Items 9 to 12)*

Learning strategy	Response option	% [CI]
Doing practice tests[a] (e.g., past papers)	Doing practice tests when I study/revise will help me to know how well I have learnt the information for the science test.	53.3 [47.1, 59.5]
	Doing practice tests when I study/revise will help me to learn and remember the information for the science test.	33.8 [28.4, 39.6]
	I do not think doing practice tests when I study/revise will help me to learn and remember the information for the science test.	12.9 [9.6, 17.1]
Spaced practice	Spacing out my study/revision sessions over multiple days/weeks will help me to learn more information for the science test.	27.6 [22.0, 34.0]
	Spacing out my study/revision sessions over multiple days/weeks will help me to learn and remember the information for the science test.	58.5 [52.1, 64.6]
	I do not think spacing out my study/revision sessions over multiple days/weeks will help me	14.0 [10.4, 18.6]

Learning strategy	Response option	% [CI]
	learn and remember the information for the science test.	
Flashcards	Using flashcards when I study/revise will help me to learn because it allows me to read the information over and over.	15.9 [12.3, 20.4]
	Using flashcards when I study/revise will help me to learn because it allows me to practise bringing the answer to my mind.	32.1 [25.2, 39.9]
	Using flashcards when I study/revise will me to learn because it helps break up the information into smaller amounts to practise.	32.1 [28.0, 36.4]
	I do not think using flashcards when I study/revise will help me learn the information for the science test.	19.9 [15.1, 25.8]
Mind maps	Using mind maps when I study/revise will help me to learn because it allows me to read the information over and over.	20.4 [17.3, 24.0]
	Using mind maps when I study/revise will help me to learn because it allows me to practise bringing the information to my mind.	21.9 [16.4, 28.8]
	Using mind maps when I study/revise will help me to identify the main topic and link this to related topics, with words that make sense to me.	41.1 [34.9, 47.5]

Learning strategy	Response option	% [CI]
	I do not think using mind maps when I study/revise will help me learn the information for the science test.	16.6 [12.8, 21.2]

Note. [a]In the present study, we used term *practice tests* to refer to retrieval practice in the ERaSSQ survey.

Do secondary schools currently provide students with support for study/revision? Is there a demand for information about evidence-informed learning strategies?

To further evaluate whether there is a need to provide additional information and support on the use of evidence-informed learning strategies in secondary schools, we asked whether schools offer students assistance with study/revision skills for science. Table 3.10 shows the weighted percentages of students reporting whether schools offer advice on study/revision skills to support students with independent work. Finally, we asked students if they were interested in learning about evidence-informed learning strategies to help them study/revise more effectively. Table 3.10 shows the weighted percentages of students reporting whether students should be provided with information about effective learning strategies, and if they were interested in receiving this information.

Table 3. 10 *Weighted percentage scores for student responses to the survey questions about availability and demand for support with study/revision (Survey Items 14 to 16)*

Survey item	Response option	*%*	*SE*
Does your School Offer all Pupils in Year 10 Study/Revision Skills Support to Help you Study/Revise for Science?	Yes	76.5	3.8
	No	8.3	2.2
	I don't know	15.2	2
Do you Think That you Should be Provided with Information About Effective Learning Strategies to Help you Study/Revise for Science?	Yes	96.1	1.3
	No	3.9	1.3
Would you be Interested in Receiving Information about Evidence-Based Learning Strategies that Will Help you to Study/Revise Effectively for Science?	Yes	81.7	2.5
	No	18.3	2.5

Discussion

We report results of the first regional survey to evaluate the use and understanding of learning strategies by secondary school students (aged 14-15 years) in mainstream schools in the UK to study and/or revise in preparation for science examinations. In addition, we report the effort students' make towards independent study and revision, and the advice they receive from schools. In the following section, each of these aspects of students' study practice are discussed. Although this study is based on students in North Wales, the findings, based on more representative methodology, are likely to generalise more broadly to students in other regions of the UK where students follow very similar science qualifications in comparable school settings.

Use of learning strategies

Our results showed that less effective learning strategies were most frequently used by secondary students, including making notes, repeatedly reading information, highlighting or underlining information. Retrieval practice and spaced practice (i.e., more effective strategies) were less commonly used by students, and these findings align closely with the outcomes of previous studies which found that secondary students relied on less optimal learning strategies (Agarwal et al., 2014; Dirkx et al., 2019). Oakes and Griffin (2016) also found that students studying advanced level academic courses in the UK (aged 16-17 years) similarly relied on less optimal learning strategies (i.e., reading approaches and highlighting information) as opposed to more effective ones such as retrieval practice, suggesting the results in this study might generalise to the wider secondary school population. Importantly, the findings from this study, based on a robust sampling methodology, confirm that secondary learners rarely make use of the most effective learning strategies.

When considering students' use of more and less effective strategies, in the present study, students reported highlighting or underlining information more frequently than using retrieval practice. In contrast, Dirkx et al. (2019) report that students more frequently reported using retrieval practice activities, followed by highlighting/underlining information. Dirkx et al. (2019) suggested that the nature of the question format in such surveys (e.g., open-format with students reporting the strategies, or closed-format with students selecting strategies from a predefined list) might influence student reports of strategy use. The present study included nine common learning strategies and presented these in a list whilst providing students the opportunity to report any additional strategies they use. By providing students with a list of learning strategies, our aim was to ensure students did not overlook any common learning strategies they use. This study used a response scale based on how often each strategy was used, giving students the choice to select a response option from *never* to *always* for how frequently, if at all, students used each strategy. This approach provided a more valid indicator of strategy use.

Other factors that could have contributed to the difference between the Dirkx et al. (2019) and the present study may be related to the study design (i.e., sampling methodology) and/or cultural differences between students in the Netherlands and the United Kingdom. The present study used a stratified random sampling method to ensure the sample represented different student ability groups, whereas the Dirkx et al. (2019) study did not specify the sampling methodology that was employed in the three participating Dutch secondary schools.

How does students' understanding of learning strategies relate to their use of learning strategies?

The present study has shown that learners do not generally have an accurate understanding of the effectiveness of the learning strategies they most frequently use. The learning strategies students ranked as effective for learning were lower utility strategies such as making notes, repeatedly reading information and highlighting or underlining information.

This might suggest that students are not using more effective learning strategies due to inaccurate and/or incomplete understanding about the effectiveness of both the learning strategies they use and the alternatives that are available. This finding has important implications for developing learning programmes on the study habits of students as well as providing useful information for both schools, school improvement professionals and also providers of teacher initial education.

We also found that over half (53.3%) of students reported they identify retrieval practice as a strategy to help them assess their learning (i.e., to identify what they know and/or don't know) rather than as an effective learning strategy in itself. This finding suggests that most students were not aware of the advantage of using retrieval practice as a learning strategy when studying and/or revising for science. One possible reason for this could be students' everyday experience of completing retrieval practice activities for formative and/or summative purposes in school (e.g., end of unit tests).

Most of the students (58.5%) reported that spacing practice would have helped them to learn and remember information when studying and/or revising for science, suggesting that most students understand that spacing is beneficial for learning. However, in this study spaced practice was the fifth most-commonly used learning strategy students reported using. Findings from a study by Susser and McCabe (2013) indicate that university students were aware of the spacing advantage, although these older learners similarly reported using this strategy less frequently compared to more suboptimal strategies, such as repeated reading. The inconsistency between learners' understanding and utilisation of spaced learning may be partly to do with a lack of knowledge about the learning advantage of spaced practice (i.e., the spacing effect), which can help to slow down the rate of forgetting newly learned information (Bahrick, Bahrick, Bahrick & Bahrick, 1993; Ebbinghaus, 1885/2006). Another tentative explanation is that spacing is a strategy based on *when* learners should practice instead of *how* to practice and, therefore, students might not have considered spaced practice as a learning strategy when completing the survey.

Effort towards independent study and revision

This study also evaluated the effort students make towards independent work (i.e., time spent studying and revising) and the advice they receive from school teachers. Our data show that students reported spending more time revising in the weeks leading up to a science test (3 to 4 hours) than spent studying in a typical week (less than 1 hour). These findings are in line with results from Agarwal et al. (2014) who also reported students spending more time studying and revising when there was an upcoming test compared to in a typical week when there were no exams. As students appear to distribute their independent study and revision time unevenly, they are unlikely to be able to use spaced practice as an effective strategy (which is based on implementing a regular schedule of study practice that spreads activities over time). The present study highlights the need to inform students about distributing their independent study and revision efforts more evenly over time to successfully incorporate effective learning strategies.

Support with study and revision strategies

Most students in this study (92.7%) reported that their science teacher(s) encouraged them to use retrieval practice. However, when interpreting these promising results, it is important to consider that we have previously noted that most of the students reported they would complete retrieval practice to assess their learning rather than as a learning strategy. This finding suggests that although schools are promoting retrieval practice, students are not using this strategy to its maximum potential. One reason students might not be using retrieval practice as a learning strategy could be due to their everyday classroom experience of teachers using tests for summative and/or formative purposes. Moreover, students also reported that their science teacher(s) encouraged the use of lower utility strategies such as making notes, repeatedly reading information and highlighting or underlining information. Our findings suggest there is an important role for teachers to promote retrieval practice as an efficient learning strategy. Further research now needs to focus on teachers' understanding of retrieval practice and other high utility strategies, and how best to communicate this information to learners.

Use of additional learning strategies

This study allowed students to report any additional learning strategies they use for independent study and revision. Interestingly, student responses to the open-ended questions included examples of how students had modified the use of some of the nine predefined learning strategies included in this study (e.g., making notes, retrieval practice). A possible explanation for this might be that although students encounter general descriptions of how each strategy can help them learn, they are likely to adapt and modify some of these strategies. For example, there are various ways for learners to make notes (including handwritten and typing on a digital device) as well as various study tools for making notes (including, posters, post-it notes) (Witherby & Tauber, 2019). Student responses to the open-ended questions reflected how students' applied these more versatile learning strategies during independent study. Some strategies are more versatile than others in terms of *how* they can be applied, and this might have resulted in more students reporting on these strategies in the open-ended answers compared to other less versatile approaches. Future research using qualitative methods (i.e., semi-structured interviews, focus groups) is needed to understand the variation of secondary students' strategy use and the reason behind those choices.

Implications for educators

The present study highlights the need to improve awareness about the relative utility of learning strategies used by students. In particular, our results suggest that as an important first step, secondary students would benefit from receiving training in using more effective learning strategies such as retrieval and spaced practice. Our results also suggest that educators should inform students about: (1) which are the more- and less effective learning strategies; (2) the benefits of using retrieval and spaced practice as learning strategies; and (3) how each strategy works and the practical application for independent study.

Strengths and limitations

We acknowledge some limitations in the current study. In survey item three, students were required to report and rate the three learning strategies they most frequently used for study/revision. As a result, the total number of students rating each learning strategy was small and the mean ratings for the students' perceived effectiveness of the various learning strategies may not be statistically significant. Also, we do not have information on students' opinions of other study strategies that they might use less frequently. Despite these limitations, this is the first study to report on secondary students' study and revision habits from a representative sample of 14-15 year old students in mainstream schools in the UK. As our responses included a stratified, random sample of learners from different ability groups, the results are less likely to be biased towards over- or under-reporting due to students who were more- or less interested in study and/or revision. Our findings are also less likely to be distorted due to chance under-representation of student groups.

Conclusion

This is the first study to employ a robust sampling methodology aimed at gaining a more accurate understanding of learners' use of study strategies. It is also the first study to provide a detailed insight into the use of learning strategies by secondary students in the UK to study and revise in preparation for GCSE science exams, and the first to assess students' understanding of the most frequently used learning strategies, the effort students make towards independent learning and the study advice schools provide to students. Our results indicate that students predominantly rely on less effective learning strategies for independent study and revision and do not realise some of the strategies they most frequently use are less effective approaches. The findings here also support the outcomes from previous studies. Further research should now: (1) focus on the practical barriers to secondary students' use of effective learning strategies; (2) explore whether students' use of learning strategies predicts their actual learning outcomes.

Study 2: The Influence of COVID-19 on the Independent Study Habits of Learners

Sultana, F., Watkins, C. R., & Hughes, J. C (under review). *The Influence of COVID-19 on the Independent Study Habits of Learners.* Report submitted.

In 2021, we were successful in obtaining a research grant from the Welsh Government to extend the first study on secondary students' use and understanding of learning strategies outlined in Study 1 in this chapter. The second study is a survey evaluating the influence of the COVID-19 pandemic on secondary aged students' independent learning practice that was commissioned by the Welsh Government and builds on our previous survey research described in this chapter. In this section we present a summary of the second study and discuss the findings and implications of the study. Welsh Government have given their permission for the full report to be included in Appendix E.

We conducted a survey with secondary school students to understand the influence of the COVID-19 pandemic on the independent learning practice of 14–15 year old and 16–17 year old students in Wales. During the COVID-19 pandemic school closures from March 2020, all students (except for vulnerable students and the children of key workers) remained at home and were taught remotely. Given the change in the delivery of schoolwork as well as the increased autonomy on students to undertake independent learning during the pandemic, it was important to investigate any change in students' independent learning practice. Existing studies into the impact of the pandemic with students in secondary and further education in Wales explored what learning resources students were using for home learning. However, those studies did not explore what learning strategies students might have used whilst accessing information using learning resources (i.e., how students' were learning the information and ideas on their own). In Study 2 we explored students' experiences of using a variety of learning strategies and learning resources for independent learning (i.e., to complete schoolwork, study and/or revision) whilst at home, the time spent on school work and study, and how they felt about independent learning skills and using digital learning platforms. Importantly we also evaluated learners' understanding of learning strategies and resources.

We conducted a cross sectional survey with students aged 14–15 and 16–17 years in mainstream middle and secondary schools in Wales. We used a multistage clustered sample design for a sample selection. At the first stage of the sampling process, we randomly selected a sample of maintained middle and secondary schools in Wales from a list of all schools using an implicit systematic sampling method. At the second stage, we invited all students in Year 10 and Year 12 from the selected schools to complete a modified version of the Effective Revision and Study Strategies Questionnaire (ERaSSQ). We modified the ERaSSQ survey to reflect appropriate changes in students' education that relate to the COVID-19 pandemic. These included use and understanding of learning resources, confidence towards using digital learning platforms, confidence on using independent learning skills and activities, and sourcing knowledge on learning strategies and resources.

Despite the need for students to work more independently during the COVID-19 school closures, we found similar results to those presented in Study 1. Our results showed that students reported using both less and more effective learning strategies whilst learning at home. Our data also suggest that students do not have an accurate understanding about the effectiveness of some common learning strategies. These findings suggest that students’ use and understanding of learning strategies have not changed significantly since the start of the COVID-19 pandemic, and highlights the need for schools to continue to improve awareness about effective learning strategies and resources in Wales. In addition to investigating *what* learning strategies and resources students were using, we also examined where students' knowledge about learning strategies and resources came from (e.g., parents/carers, schools, peers), as well as students’ confidence towards independent learning skills and activities.

We also assessed how confident students felt about independent learning (i.e., independent study skill and learning activities). Our findings indicate that students’ confidence towards independent learning skills and activities has improved since March 2020. At the start of the COVID-19 school closures, learners reported feeling less confident about independent learning skills and activities, whereas at the end of the COVID-19 pandemic, learners’ expressed increased levels of confidence towards the same independent learning skills and activities.

Study two further highlights the need to improve students' awareness about independent learning skills, as well as awareness about the utility of common learning strategies used by learners in schools. These findings align closely with the outcomes of our earlier survey with secondary students outlined in Study 1 here, and suggests that students would benefit from receiving information about how to use more effective learning strategies such as retrieval practice and spaced practice. Importantly, schools and practitioners should provide students with guidance on independent learning, and effective learning strategies.

There is still a demand among secondary students for more information on effective learning strategies. In our previous survey with secondary students outlined in Study 1, 81.7 percent reported that they were interested in receiving information about effective learning strategies. The findings are similar to our second study with students that showed that most students (71.1 percent) are interested in receiving information about effective learning strategies.

In Study 2 we aimed to replicate our first study with 14–15 year old secondary students' use and understanding of learning strategies for independent work. Importantly, the findings from study 2, based on a robust sampling methodology, confirmed our study findings from the first study, and showed that secondary learners rarely make use of the most effective learning strategies.

Chapter 4: Development of the Improving Standards through Effective Revision (iStER) programme

Preface

Findings from our survey studies with secondary school students and science teachers on learning strategies highlighted the need to improve awareness about the relative utility of learning strategies commonly used by students and promoted by teachers in schools (Chapters 2 and 3). Furthermore, our findings suggested that students would benefit from receiving training in using more effective learning strategies such as retrieval and spaced practice. In addition to educating students about these effective learning strategies, our survey findings suggested that students would also benefit from learning about proactive independent learning. We have used these survey findings along with other research in cognitive and educational psychology to develop a learning resource called the Improving Standards through Effective Revision (iStER) programme to teach school students about the most effective learning strategies that enhance learning and show potential to improve academic performance.

This chapter contains a detailed description of the iStER learning resource as well as a single blind parallel feasibility randomised control efficacy trial of a lunchtime study and revision programme for learning GCSE Chemistry using the iStER programme. This was a feasibility efficacy trial conducted in advance of a future definitive RCT. The primary aims of the randomised feasibility efficacy trial is to gain experience in delivering the iStER programme to help secondary students for independent learning and to assess the feasibility of conducting a future definitive RCT using the iStER programme (with students). As such, the feasibility efficacy trial objectives were to assess trial design, school and student acceptability of the intervention, and outcome measures to provide data to estimate the parameters required to design a definitive RCT.

Introduction

Background and objectives

In Wales, the standards students achieve in science at the end of secondary school, as well as the uptake of science subjects, has frequently been the subject of debate and criticism (Wightwick, 2017a; Wightwick, 2017b, Wightwick, 2018). There have been many initiatives funded by the Welsh Government to help improve students' science standards and to inspire and encourage students to pursue science related careers (e.g., Trio Sci Cymru, Swansea University Science for Schools Initiative, The Welsh Valleys Engineering Project, STEM Gogledd programme). As part of the Welsh Government's National Strategy for Educational Research and Enquiry (NSERE) strategy and policy there has been an increasing effort to focus education provision along more evidence-informed lines (Welsh Government, 2021). The use of evidence-informed learning strategies for independent learning (i.e., study and revision) can play an important role in helping students in secondary schools prepare for external examinations to improve standards in science. Recently, there has been renewed interest in using cognitive science research in schools including the use of effective learning strategies through researcher driven websites (e.g., The Learning Scientists [https://www.learningscientists.org/], Retrieval Practice [https://www.retrievalpractice.org/why-it-works]). We developed a learning programme called improving standards through effective revision (iStER) that applies effective learning strategies (i.e., retrieval practice and spaced practice), and tested the feasibility of lunchtime study/revision sessions to learn GCSE chemistry using the programme in a randomised control trial with secondary school students in North Wales.

Over recent years there have been significant contributions to the research literature on evidence-informed learning strategies (Agarwal et a., 2021; Agarwal et al., 2014; Dunlosky et al., 2013 Sotola & Crede, 2021; Yang et al., 2021). Research suggests that two learning strategies have been shown to enhance long term learning and retention of information (Dunlosky et al., 2013; Yang et al., 2021). These strategies are retrieval practice and spaced practice. Retrieval practice is a learning strategy based on retrieving information from memory (i.e., practising recall) in absence of the information to be learnt. Spaced practice is a learning strategy involving spacing out study sessions over time and reviewing previously learnt information in successive sessions, which can help to slow down the rate of forgetting newly learned information.

There have been several books and resource guides to help use effective learning strategies in the classroom and for independent learning (Carey, 2014; Carpenter & Agarwal, 2020; Horvath, Lodge & Hattie, 2016). There have also been a growing number of web-based and smartphone learning resources developed on effective learning strategies (e.g., Seneca Learning [https://senecalearning.com/en-GB/], Quizlet [https://quizlet.com/en-gb]). However, despite the availability of a variety of online and offline learning resources to aid students in the application of the two most promising learning strategies, studies with students at all educational levels show that less effective strategies such as repeated reading approaches, summarising information and highlighting [or underlining] information are frequently used as independent learning strategies, compared to the more effective strategies (i.e., retrieval and spaced practice); our previous research with 14–15 year old secondary students' use and understanding of learning strategies for independent work also confirmed this. Our survey also showed that students do not have an accurate understanding of the utility of the learning strategies they most frequently use (i.e., do not realise some of the strategies they most frequently used are less effective). Most of the students reported that they identified retrieval practice as a strategy to help them assess their learning (i.e., identify what they know and/or do not know) rather than as an effective learning strategy in itself. These findings suggest that students have some mistaken beliefs about the effectiveness of the learning strategies they frequently use, and this might be why students continue to use these lower utility strategies. Importantly, our findings highlighted that students would benefit from learning about which are the more and less effective learning strategies.

Importantly there is also a demand for more information on effective learning strategies among secondary school students. In our previous survey we also found that students want more information about evidence-informed learning strategies to help them study/revise effectively in preparation for exams. In fact 81.7 per cent reported that they were interested in receiving information about effective strategies and 96.1 per cent believe students should be provided with information on effective learning strategies.

Studies that have explored the use of spacing practice and retrieval practice individually and using blended learning approach of spacing and retrieval practice found that these strategies enhanced learning in primary school students for science as well as other subjects and with older students in university settings (Carpenter et al., 2018; Gluckman et al., 2014; Goossens et al., 2016; Greving & Richter, 2018; Gurung & Burns, 2018). In the research literature on the application of effective learning strategies, very few studies have used more robust designs (i.e., randomised experimental designs) with secondary school students learning science. In the UK, a study by Feddern, Schechtman and Wilks (2018) investigated the effectiveness of a software programme that makes use of four learning strategies including retrieval, interleaving, spacing and visual cues in a randomised controlled trial with secondary students for learning science. Students in the study were randomly allocated to one of the three trial arms, including the software group, spacing group or massed practice group. Findings from students' post-test scores demonstrated that students in the software group scored higher than students in both the massed and spaced group. These findings add to the growing body of research literature that show how effective learning strategies can enhance student performance. In the current study, we aim to assess the feasibility of lunchtime study/revision sessions to learn GCSE chemistry using the iStER learning resource in an individually randomised controlled efficacy trial. In the current study we focused on GCSE chemistry and used a different experimental design to the study by Feddern et al. (2018). In the study by Feddern et al. (2018), the authors used a clustered randomised design (i.e., classes of students were randomised to trial conditions rather than individual students to trial conditions). The aim of the current study is to investigate whether the iStER intervention can work in an applied school setting during lunchtime sessions. Our current study outlines an efficacy randomised controlled trial. The study by Feddern et al. (2018) focused on whether the Seneca learning resource worked when applied in the real world on a larger scale (i.e., was an effectiveness trial). In contrast, we designed an efficacy randomised controlled trial of the iStER learning resource in secondary schools. We will assess the efficacy of the iStER learning resource on a small scale.

Although there are learning resources available to help students in the application of effective learning strategies, more support is needed to aid learners in the application and transfer of effective learning strategies (Biwer et al., 2020a; Biwer et al., 2020b; Mc Daniel & Einstein, 2020; Oakes & Griffin, 2016). This might be one reason why, despite the availability of evidence-informed learning resources, students at all educational levels continue to rely on suboptimal strategies. Also, these programmes make use of effective learning strategies that are embedded in the software algorithm of the resource and are, therefore, not explicitly taught to students. Another limitation is that existing programmes do not teach students about proactive independent learning, the importance of effort (i.e., investing time), nor about the relative utility of other commonly used learning strategies. Recently McDaniel and Einstein (2020) proposed the knowledge, belief, commitment and planning (KBCP) model for guiding strategy training to support students' successful use of effective learning strategies on their own. In brief, the KBCP framework is underpinned by the assumption that there are four key components which must be included in training to support students' sustained strategy use. These are: (1) acquiring knowledge about strategies; (2) belief that the strategy works; (3) commitment to using the strategy; and (4) planning strategy implementation. In another model, Oakes and Griffin (2016) proposed five behaviours and characteristics that all students need to be successful, independent learners. These qualities are vision, effort, system, practice and attitude, called the VESPA system. With these issues in mind we developed the iStER learning resource.

The iStER learning resource teaches students about proactive independent learning, effort (i.e., investing time for independent work), how we learn, the utility of common learning strategies, and how effective learning strategies help us to learn and remember information (i.e., provides students with the knowledge about proactive independent work and about learning strategies). In addition to helping students acquire knowledge about proactive independent work and learning strategies, to promote the use of effective learning strategies, we developed iStER resource packs which contain materials and evidence-informed approaches to help students develop the habit of independent work and use effective learning strategies for their independent learning and revision. iStER provides a system to help students organise their learning resources and time.

The iStER programme is aimed at secondary school students aged 14–16 years. It is designed to encourage independent work (i.e., study, revision), promote the use of effective learning strategies to maximise students independent learning and raise awareness of and normalise independent work using the behavioural influence of social norms. The iStER programme provides a system including resources packs for students to organise their independent learning time and activities and practice using effective learning strategies. The materials in the iStER resource packs are presented using principles of effective instruction associated with positive educational outcomes and derived from the learning sciences

(Fredrick & Hummel, 2004). For the current feasibility trial, we used the iStER programme with five topics from the GCSE chemistry syllabus. The topics included atomic structure, chemical calculations, formula and equations, nature of substances and chemical reactions and the periodic table. The content was written by a GwE school improvement adviser for science and WJEC chemistry chief examiner.

The aim of the present study was to test the feasibility of using the iStER programme to help secondary students in Year 10 learn GCSE chemistry during lunchtime revision sessions. We designed this study as a feasibility randomised controlled trial to inform a later more definitive trial. The current study is an efficacy randomised controlled trial research design. The primary objectives of the feasibility efficacy trial were: (1) to assess school and student acceptability of the intervention (2) to examine whether parents and carers would be willing for their children to be randomised to one of the trial arms; (3) assess how many parents/carers and students accepted the invitation to participate in research; (4) assess retention of students to lunchtime sessions by estimating weekly session attendance rates; (5) assess student engagement with the iStER programme by estimating weekly session attendance rates, retention rates, use of iStER resource packs; and, (6) to test study feasibility for lunchtime study and revision sessions for using the iStER programme (i.e., do lunchtime sessions for using the iStER during school hours work?). In addition the study aims to establish suitable procedures for delivering the iStER programme for a future definitive RCT.

Togerson and Togerson (2001) outlined that RCT's can measure small educationally important changes that may result from educational programmes. Therefore, to explore the present study aims we used a strong study design in the form of a waiting-list randomised controlled efficacy trial to explore the feasibility of implementing the iStER programme with Year 10 GCSE students during lunchtime study sessions. We compared a group of students who received the iStER programme to that of a similar group of students who received the chemistry study materials and to that of a similar group of students who received ‘science as usual’ teaching within a secondary school setting. The main objective of a future definitive RCT is to evaluate the use of iStER to determine the effectiveness of the programme to improve secondary school students' learning, academic performance, and independent learning skills of students receiving the programme. For the current study, it was important for us to develop an evidence base for the intervention. This has been a focus with the current project and others in the Collaborative Institute for Education Research Evidence and Impact and our school partners in the Regional School Improvement Service for North Wales (Owen et al., 2022). Our current feasibility trial is at the efficacy level in the adapted model Owen et al. (2022) proposed for an evidence building framework for education interventions. Importantly answers to the above questions will inform decisions as to whether the program is ready to be scaled to an effectiveness trial.

Methods

Trial design

We employed an efficacy three-arm individually randomised parallel (waiting list) group design. Our trial was randomised at the individual level, with students within classes randomised to one of the three trial arms (conditions). These were (1) the ‘iStER intervention group’, (2) ‘chemistry study group’; and (3) ‘wait-list control group’. The current study involved students in a school setting, with students grouped together in classes as part of their daily school activities (i.e., lessons). We recognised that this might cause contamination through peer learning (i.e., bleeding effects). To control for any such contamination, we planned to deliver the trial during lunchtime hours in a science classroom on school premises (where the trial materials would be collected at the end of each session). Students in the iStER intervention group were invited to attend supervised lunchtime sessions to study/revise independently using the iStER resource packs with all resources collected by the research student at the end of each session. We recognised that such arrangements would introduce a confounding variable (i.e., research student/science teacher time and attention). To help us control for the confound of a researcher/science teacher we included a third arm to the efficacy trial, which was the ‘chemistry study group’. Students in the chemistry study group were invited to attend weekly lunchtime sessions to study/revise independently using the same chemistry content presented in a booklet with sessions supervised by a science teacher and all resources collected at the end of each session.

In total twelve students were randomly assigned to the control group (‘science as usual). One of the student’s assigned to the control group was mistakenly flagged in the school register to attend the chemistry study group introductory session. The student arrived for the chemistry group study session for which reason we decided to keep the student on the chemistry study group for the feasibility trial.

Participants

This five-week parallel three-arm feasibility trial took place in a secondary school in North Wales from February to March 2019. An overview of the feasibility efficacy trial timeline is presented in Table 4.1.

Table 4. 1 *Overview of feasibility trial timeline*

Activity	Description	Date
Sampling	Using an anonymised Excel spreadsheet list of Year 10 students provided by the school to select a sample of students	January 2020 (23/01/2020)
Recruitment	Send study information forms to the selected students for parental and carer consent	January - February 2020
Pre-test data collection	Blind assessor to administer the pre-test to all participating students	February 2020 (07/02/2020)
Randomisation	External researcher not associated with the trial to carry out randomisation procedure	February 2020 (14/02/2020)
Post-test data collection	Blind assessor[1] to administer the pre-test to all participating students	March 2020 (23/03/2020 - or was it the Friday check)

Note. [1]In the feasibility trial protocol we proposed to employ a blind assessor to administer the pre and post-test assessments. Due to the COVID-19 outbreak we stopped the pilot trial earlier and a blind assessor from our project partner administered the post-intervention assessment to students.

We recruited one secondary school in North Wales through our project partners in the Regional School Improvement Service for North Wales (GwE). The inclusion criteria for the school were (1) mainstream maintained secondary school in North Wales (in the UK); and (2) secondary school with students enrolled in Year 10. The trial was stopped two weeks earlier than the end date due to the COVID-19 pandemic outbreak.

Recruitment, screening, randomisation and blinding procedure

In total thirty-four students were recruited from the secondary school in North Wales in January 2019. The inclusion criteria for students were (1) students aged between 14 and 15 years (school Year 10); and (2) students studying either triple GCSE science award or double GCSE science award. In January 2020, the deputy headteacher and nominated science teacher at the participating school identified potential student participants that met the study inclusion criteria (and emailed an anonymised list of the eligible Year 10 students science award information to the research team to select a sample of students). There were 146 eligible students in Year 10.

We used explicit simple random sampling to select a sample of students from Year 10 for the needs of the trial (i.e., to ensure that the sample of students is representative of different academic ability levels in school science). This was because school science classes were set by student ability. In addition to ensuring that the sample of students was representative of different student ability levels, it was important to ensure that the sample was not biased to students who were more academically able and/or more interested in study/revision and therefore more likely to volunteer to take part in the trial. Also, this would ensure that the sample would not under-represent students who were less academically able and/or less interested in study/revision and therefore less likely to volunteer to take part in the trial. This would also help to avoid any potential ceiling effects with recruiting more academically able students. Therefore, we randomly selected a sample of students from an anonymised list of students provided by the participating school. To ensure that the sample of school students represented different ability levels, we used an anonymised list of Year 10 students sorted according to the science qualification they were studying (e.g., all students studying triple GCSE science were listed, followed by all students studying double GCSE science in a separate column). The science qualification information was then used as a proxy indicator of students' academic ability in school science (i.e., more academically able students typically follow triple science award, with the remaining students generally following the double science and BTEC/applied science qualifications [students following BTEC/applied science qualifications were not eligible for this study due to the difference in subject specification they followed]).

As mentioned above, school science classes were set by student ability, and it was important to have balanced numbers of students in each trial arm. Importantly, this would provide a realistic experience in delivering the trial (iStER programme) to students within school settings where students are generally grouped in classes for science/ where school science classes are set by student ability. This would inform us about the practicalities of delivering the iStER programme within school settings where students are generally grouped in classes for science. We used one stratification variable (randomisation criteria), which was the science qualification students were following (i.e., triple, or double science).

We sent the study information and consent letters to the school, and these were forwarded to the parents and carers (see Appendix F). This informed parents and carers about the aims of the study and our intention to randomly allocate their children into the iStER intervention, chemistry study, and control groups. The study information sheet also explained that students in the chemistry study and control groups would also receive the iStER intervention following the end of the five-week efficacy trial by the research student who delivered the training for the current trial. Parents and carers who were interested in their child participating in the trial completed the opt-in consent forms and returned these to the nominated science teacher. In January 2019, we obtained consent from parents and carers of thirty-four students.

Once we had obtained parental and carer consent the thirty-four students were administered the pre-test measures described in the following section, by a blind assessor. We employed an independent data collector who was not involved with the study to conduct the pre-intervention assessment. A standardised introduction was given to all the students (see Appendix G containing the script for the blind assessor). We obtained student assent prior to students completing the pre-test assessments. Four students were absent on the day of the first pre-test. These students were not included in the randomisation.

An external researcher not associated with the feasibility trial carried out the randomisation for the trial using Microsoft Excel. We emailed the students information (i.e., science award qualification [list of students following triple science and a list of students following double science to the external researcher]). The external researcher carried out the randomisation procedures, allocated the thirty-four students to one of the three trial arms using the randomisation function in Excel, and emailed a password protected copy containing student allocation information to the research team the following day. The thirty-four students were individually randomised allocated to the intervention 'iStER group', 'chemistry study group' or 'waiting-list control group', with twelve in the waiting-list control, eleven in the chemistry study and eleven in the iStER intervention group.

We planned for an independent data collector who was not involved with the study to conduct the post-intervention assessment, so the tester would be blind to which group each student belonged. Due to the COVID-19 outbreak we stopped the pilot trial earlier and a member of the research team from our project partner administered the post-intervention assessment to students.

Intervention (iStER, chemistry study or waiting-list control)

An overview of the efficacy trial phases and groups is presented in Table 4.2. In reporting the interventions, we followed the template for intervention description and replication (TIDieR) checklist and guide.

Table 4. 2 *Overview of efficacy trial phases and groups*

Trial phase	Trial group		
	iStER	Chemistry study	Control
Pre-test and introduction to study	75 minutes	75 minutes	75 minutes

Trial phase	Trial group		
	iStER	Chemistry study	Control
Phase 1	40 minutes of class time to receive iStER training and information about the lunchtime study sessions	20 minutes of class time to receive information about the chemistry topics and lunchtime study sessions	Attend timetabled chemistry lessons as usual
Phase 2	10 minutes (or more) during lunchtime in a science classroom to study chemistry using iStER resources, for 3 sessions per week	10 minutes (or more) during lunchtime in a classroom to study the chemistry topics presented in booklets using students usual learning strategies, for 3 session per week	Attend timetabled chemistry lessons as usual
Duration of trial[1]	Five weeks	Five weeks	Five weeks
Post-test	45 minutes	45 minutes	45 minutes

Note. [1]The original duration of the trial was 5-weeks, due to the COVID-19 pandemic outbreak the trial was stopped two weeks earlier.

The duration of the programme was the same for the iStER group and the chemistry study group, and this was a five-week long programme. Also, the amount of time (i.e., number of lunchtime sessions) required for participating in the lunchtime sessions to study/revise independently was the same for the iStER group and the chemistry study group. The only differences included the learning resources students were provided for the training and lunchtime sessions and the amount of time required for the introductory training sessions. At the first session, the research student explained the procedure for the respective intervention (iStER or chemistry study), showed students the learning resources available for the iStER or chemistry study sessions and the research student familiarised students with the resource packs (Appendix H contains the PowerPoint presentation slides for the iStER group and Appendix I contains the presentation slides for the chemistry study group) and with the weekly lunchtime study/revision routines for the five-week programme (Appendix J contains the timetable for the iStER group and Appendix K contains the timetable for the chemistry study group). As part of the five-week long programme students were required to attend three weekly sessions to independently study using the resource packs and complete the study/revision routines. Following the training session for the respective intervention, students started using the learning resources to independently study GCSE chemistry during lunchtime hours in a science classroom on school premises. At the end of the training session, students did not receive any further instructions on how to use the resource packs nor about the lunchtime sessions from us, and were informed that all instructions as well as copies of the respective intervention presentation slides were contained in their resource packs.

Moreover, for the feasibility RCT, the chemistry content covered five GCSE topics. These topics were, atomic structure, chemical calculations, formula and equations, nature of substances and chemical reactions, and the periodic table. The topics were taken from the WJEC chemistry exam board, and was commissioned from a chemistry specialist from our project partners in GwE. The chemistry content provided to students in the iStER group and the chemistry study group was the same. The only difference was the format used to present the chemistry content. For students in the iStER programme, the chemistry content was presented on flashcards (called iStER cards) to help students practise learning using retrieval practice (Appendix L contains a PDF version of an example of iStER flashcards containing the chemistry content, students received these as packs of cards). In total there were 110 iStER flashcards containing the chemistry content. Students in the chemistry study group received A4 booklets containing the same chemistry content (see Appendix M).

Improving standards through effect revision (iStER) intervention

A summary of the iStER intervention group can be found in Table 4.2. During phase 1 students in the iStER group participated in the iStER training session in a classroom on school premises. The training session involved a presentation (and practical session) delivered by the research student and lasted approximately 50 minutes (duration of one school lesson, 45 minutes for the iStER training and 10 minutes to give feedback on the presentation). During the iStER presentation we introduced students to the iStER programme and outlined the key concepts of the programme which included teaching students about proactive independent learning, investing time towards independent study, which are the more and less effective learning strategies (a more detailed description of each of these aspects is given below). We then gave students their individual iStER resource packs and provided a step-by-step demonstration on how to use the iStER resources independently to study GCSE chemistry in school during the organised weekly lunchtime study/revision sessions (Appendix H contains a copy of the PowerPoint presentation and training slides).

Demonstration on how to use the iStER resource packs

First to encourage students to develop the habit of proactive independent study and to break any barriers students might have to avoid independent work we taught students about the Ten Minute Rule activity. It involved telling students to undertake ten minutes of intense work, that's all, we told students that they were only expected to study the chemistry content for a minimum of ten minutes, although they could study for longer if they wanted. Once students have their resource packs, students first take out the iStER calendar which contains information on which file of card they should practise (i.e., green study file, red review file or yellow review file). If the calendar shows the study green file, students take out the green file which contains the pack of chemistry cards that students need to learn. Students were shown first to shuffle the cards (to avoid any order effects) and then before students start to learn the cards they write down the date and time they start, using the iStER calendar where it says time start. Students then spend ten minutes learning the content on these cards using retrieval practice. To learn using retrieval students were instructed to first read the question, before turning the card to see the answer, students were instructed to *remember* and *write down* the answer to the card in their iStER journals. Students can then turn the card to see if the answer they have written down is correct/incorrect. When students correctly remembered and wrote down the answer to a card, the card could be moved to the red file. If students could not remember the answer correctly then the card goes back into their green file. Students go through the rest of the cards in the pack in the same way. After 10 minutes students can stop or alternatively carry on, it is up to them. Once students have stopped they write down what time they finished using the iStER calendar record label where it says time finish. Before returning the resource packs to the research student, students also complete the iStER record label, so they write down the date, the time they started and finished and place the sticky label in the page where they finish the day's study.

Using the resource packs we gave students the above mentioned demonstration on how to use the red and yellow review files. Students were instructed to follow the exact same procedure when reviewing the cards in the red and yellow files. When reviewing the cards in the red file using the same process outlined above for the green file, students were taught if they struggle or cannot remember the answer to the cards then they have to move the card(s) back to the green file (for frequent study) or the yellow file if they can remember and write down the answer without any struggle. When reviewing the cards in the yellow file, using the same process outlined above for the green and red file, students were taught if they make any mistakes or struggle to remember the answer at all then they have to move the card(s) back to the red file for more frequent review, if however, they can remember and write the answer easily without any struggle then it can stay in the yellow file. This is based on an effective practice and recall strategy called the Leitner system (Tamm, 2023; Wadsworth, 2022), a common system for flashcards implementing systematic spaced learning. Leitner's system for organising cards into boxes was designed to prevent students from focusing on cards they know well and avoid cards they might be struggling with. For the current study we chose to use files.

The weekly supervised lunchtime study sessions at the school began for students with the research student giving students their individual iStER resource packs. Students then found a space in the classroom to sit down and started using the iStER packs using the steps mentioned above to study chemistry on their own. The duration of the lunchtime study/revision session was 40 minutes (12:50-13:30). Students were only required to attend for a minimum of ten minutes (as part of the Ten Minute Rule activity), anytime between the start and end of their lunch break, however they could study for longer if they wanted. Once students finished studying using the iStER resource packs for the session, the resource packs were returned to the research student, and students left for their next lesson. The role of the research student at the lunchtime sessions was to collect feasibility data and to direct students to the resource packs for instructions on how to use the packs if students needed reminding.

We identified key aspects of students' learning practice following a review of the literature and our own survey studies presented within chapters 2 and 3, which we have incorporated into the iStER training session. These were covered in the presentation and included:

Reactive and proactive independent study. During the presentation students were first taught about reactive and proactive independent learning and the distinction between study and revision. Oakes and Griffin (2016) proposed independent study as falling into two categories: reactive and proactive. Reactive independent study involves completing work by teachers and should form a small proportion of learners' time. Proactive independent study is work learners set themselves to do. It was important to first help students understand the distinction between independent work and work assigned by their teachers, as well as the distinction between the study and revision.

Effort towards independent learning. Next, students were taught about the importance of effort (i.e., investing time) towards independent learning to be successful learners. In Oakes and Griffin's (2016) VESPA system, the authors outlined 'effort' (i.e., investing many hours of proactive independent study) as an important quality students need to be successful learners. Oakes and Griffin further proposed one way to help students understand the importance of effort and to encourage high levels of effort is to promote studies of successful individuals. In the iStER presentation we promoted a study by Bloom (1985) with world class tennis players, which showed that the tennis participants 'willingness to invest great amounts of time and effort' were significant factors in their success. Furthermore, we promoted Oakes and Griffin's (2016) own research with secondary students which showed that their highest achieving students would invest time towards proactive independent study.

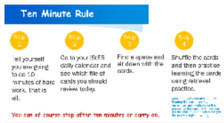
Learning strategies. Next, students were introduced to common learning strategies for independent study/revision and taught about the utility of these commonly used learning strategies among student populations. We then focused on the effective learning strategies (i.e., retrieval and spaced practice). We provided students with the knowledge about effective learning strategies (i.e., theory, definitions, examples, how these strategies can help students to learn, benefits of using these strategies). To help students use retrieval practice and spaced practice for independent learning we developed the iStER resource packs.

Once we have introduced students to the relevant theory for the iStER programme, the students then took part in the practical session which involved giving students individual iStER resource packs and a step-by-step demonstration on how to use the resources to learn using evidence-informed approaches and effective learning strategies (i.e., spaced and retrieval practice). A description of the resource packs is given below.

How to use the iStER resource packs

iStER resource packs. The contents of the iStER resource packs are presented in Table 4.3.

Table 4. 3 *List of iStER materials contained in iStER resource packs*

Item	Purpose	Image
iStER files	To use effective practice and recall strategy, called the Leitner system. To effectively organise cards (prevents students from focusing on cards they know well, and avoid cards they might be struggling with).	
Ten Minute Rule Sheet	To develop the habit of independent study/revision	
iStER pack of cards	To learn content using retrieval practice. Provides immediate feedback.	
iStER diary	To write down answers to the cards.	
Record labels	To keep a records of study/revision sessions.	
iStER calendar	To space out learning	
iStER training presentation slides	Reminder about effective learning strategies	

Our survey with secondary students presented within Chapter 3 showed that most of the students reported that they spend less than one hour in a typical week studying for science outside of the classroom.

Ten Minute Rule activity. To encourage students to develop the habit of proactive independent study we used the Ten Minute Rule activity, described previously. This is an effort activity which helps to break barriers students might have to avoid independent work. It involves telling students to undertake ten minutes of intense work, that's all. As part of the iStER programme, we told students that they were only expected to study the chemistry content for a minimum of ten minutes, although they could study for longer if they wanted.

iStER Flashcards. The chemistry content was presented on flashcards. One way to help students apply retrieval practice is using flashcards. Flashcards are a versatile study tool which can be used to practise retrieval practice, for example, we instructed students to first read a question and then practise remembering the answer. Flashcards also give immediate feedback, a principle of effective instruction (Hughes et al., 2007; Hunter et al., 2016).

Leitner system. We included labels on the files with instructions to remind students how to use the files to organise the iStER flashcards and when to move cards between the different files (see Appendix N).

iStER calendars. To help students know which file of cards they should study we provided students with calendars which show them exactly which file they should study/revise in a particular session (Appendix O contains a copy of the iStER calendar). On certain days the iStER calendar showed students had to practise cards in the more than one file (i.e., red review file and green study file), this was to ensure that if students did not yet have any cards in their review files then they could still practise learning the cards in their green study file. In addition to ensuring that there were sufficient cards for students to study in each session, the cards in the review files were the cards students were more familiar with so should take less time to go through.

iStER journals. To prevent students from turning the cards to see the answer, we provided students with journals in which students had to first write down the answer to a card before turning the card to see if the answer was correct/incorrect.

Chemistry study group intervention

A summary of the chemistry study group can be found in Table 4.2. During phase 1 students in the chemistry study group attended an introductory session in a classroom on school premises. At the introductory sessions, the research student delivered a presentation about the study programme their school is taking part in and outlined the procedure for the five-week long programme. We then gave the students individual chemistry resource packs and familiarised students with the content of the resource packs for students to use during the lunchtime sessions.

We then showed students the chemistry revision packs to be used for the lunchtime study/revision sessions. We gave the pupils a step-by-step demonstration on how to use their study/revision timetables, and then how to use the chemistry revision packs on their own during the weekly lunchtime study/revision sessions. The introductory session for the chemistry study group required approximately 35 minutes, for the research student to explain to the students the procedure for the 5-week long revision programme, and how to use the chemistry revision packs and complete the lunchtime study/revision routines. Following the introductory session, students began using the revision packs during supervised lunchtime study/revision sessions, three times a week, in a science classroom on school premises.

The weekly supervised study/revision sessions at school for the students in the chemistry study group began by the science teacher / research student giving students their individual chemistry revision packs. Students then found a space to sit down in the classroom and began using their chemistry revision packs by themselves. The duration of each lunchtime study/revision session was 40 minutes (12:50 and 13:30). Students, however, were only required to attend for a minimum of 10 minutes, anytime between the start and end of their lunch break and could stay for longer if they wanted. Once students had finished using their chemistry revision packs, the packs were returned to the research student/science teacher, and the students left for their next lesson. Students in the chemistry study group had access to the chemistry topics in a booklet (see Appendix M).

Science as usual (waiting-list control)

Students in the control group attended their weekly science classes as usual and continued with any independent study/revision without being required to attend any additional weekly study/revision sessions.

Outcome measure (assessments and measurements)

Given that this was a feasibility trial the primary objectives were not to assess the effect of the iStER learning programme. Nonetheless, science assessments were conducted pre- and post-intervention to assess response, completeness, length and time. The following assessment were used/investigated:

WJEC chemistry previous exam paper questions aligned with the content of the iStER chemistry flashcards. The shorter version of the Effective Revision and Study Strategies Questionnaire (ERaSSQ). The Science Motivation Questionnaire (Glyn, 2011).

We also measured demand for the lunchtime study/revision session (programme) by students in the trial by measuring the follow-up rates of the students (i.e., attrition and retention rates). We recorded the number of students who completed the five-week trial as well as the number of students that dropped out before the end of the five-week trial end date.

We explored demand for the intervention (iStER programme) and lunchtime study/revision sessions by students in the trial by measuring the number of students who attended the weekly lunchtime sessions. We recorded students' attendance to the lunchtime sessions for students in both the iStER and chemistry study group.

The intervention's practicability was considered as the suitability to attend the weekly lunchtime study/revision sessions (to use the iStER packs) and was measured in terms of the number of pupils who could attend the weekly sessions. We recorded pupils’ attendance to weekly sessions and pupils were asked to report additional commitments/activities on the day(s) sessions that they had, which might have been a conflict.

We assessed engagement with the intervention by the students in the trial by measuring the use of the study/revision resource packs in terms of any entries made by students in the study/revision journals for the iStER and chemistry study group. The number of entries made by students in the study/revision journals was recorded at the end of each session. In addition to assessing engagement with the resource packs by students in the iStER group, we assessed compliance with the resource by measuring any entries made by students in the iStER journal.

For the iStER group, we further assessed engagement by measuring any change in the number of iStER chemistry flashcards in each file (green, yellow and red). The number of cards in each file was recorded at the end of each session.

Sample size

Following guidelines in the literature on sample size calculation for feasibility trials and advice from a statistician in the North Wales Organisation for Randomised Trials in Health, we planned to recruit seventy-five students in Year 10, and allocate twenty-five students to each of the three arms to the trial. Importantly, this would also provide experience in delivering the iStER programme to an average number of students in a school classroom. Would inform us about the practicalities of delivering the iStER programme.

Ethics

We obtained ethical approval for this study from the Research Ethics committee of Bangor University (ethical approval number: 2019-16566).

Results

Recruitment and retention

Timeline for initial recruitment and resource preparation

We recruited one secondary school in October 2019. We recruited students in the new school term in January 2020. Selecting and screening 35 students took three weeks. We had three weeks to recruit students, in that time we were able to recruit 35 students. The study information letters were given to 146 students on 29th January. Thirty-six consent forms were returned to the school the following week. No more outstanding forms were returned by students. At this stage, we decided to postpone the start date for the trial from Monday 10th February to the first week back from the February half-term (Monday, 24th February), to give some more time to increase our effort to recruit more students and prompt students with outstanding forms.

We organised the first pre-test session for the students who had returned signed consent forms, on Friday 7th February. In total, thirty-four students completed the pre-test on the first pre-test session. A second pre-test session was planned for the following week on Friday 14th for any students who returned consent forms by then and for any of the students who were absent on the day of the first pre-testing session. The second pre-test session did not take place because the school science contact was absent during the second week (10/02/2020-14/02/2020), and therefore we could not make further arrangements for the students to complete the pre-tests. We could no longer postpone the trial start date, as this would impact the timescale and therefore decided to start the feasibility trial with the 34 students who had completed the pre-test in the first testing session.

Retention

The thirty-four students who completed the pre-test were randomised to one of the three trial arms. Figure 4.1 outlines the flow of student participants from screening to the final analysis using a CONSORT diagram. Initially, twelve students were assigned to the control group, eleven students were assigned to the chemistry study group and eleven were assigned to the iStER group. On the day of the introductory session one of the students assigned to the control group (participant number 23) was mistakenly flagged in the school register to attend the introductory session for the chemistry study group. We decided to retain the student in the chemistry study group for the duration of the trial. For this reason we report this student's data alongside the results for the chemistry study group.

There were four students that were absent on the day of the first pre-test. These students as well as any other students who submitted consent forms between later would receive the iStER programme at the end of the trial with students in the control group.

At the iStER training session two students in the iStER group decided to withdraw from the study trial.

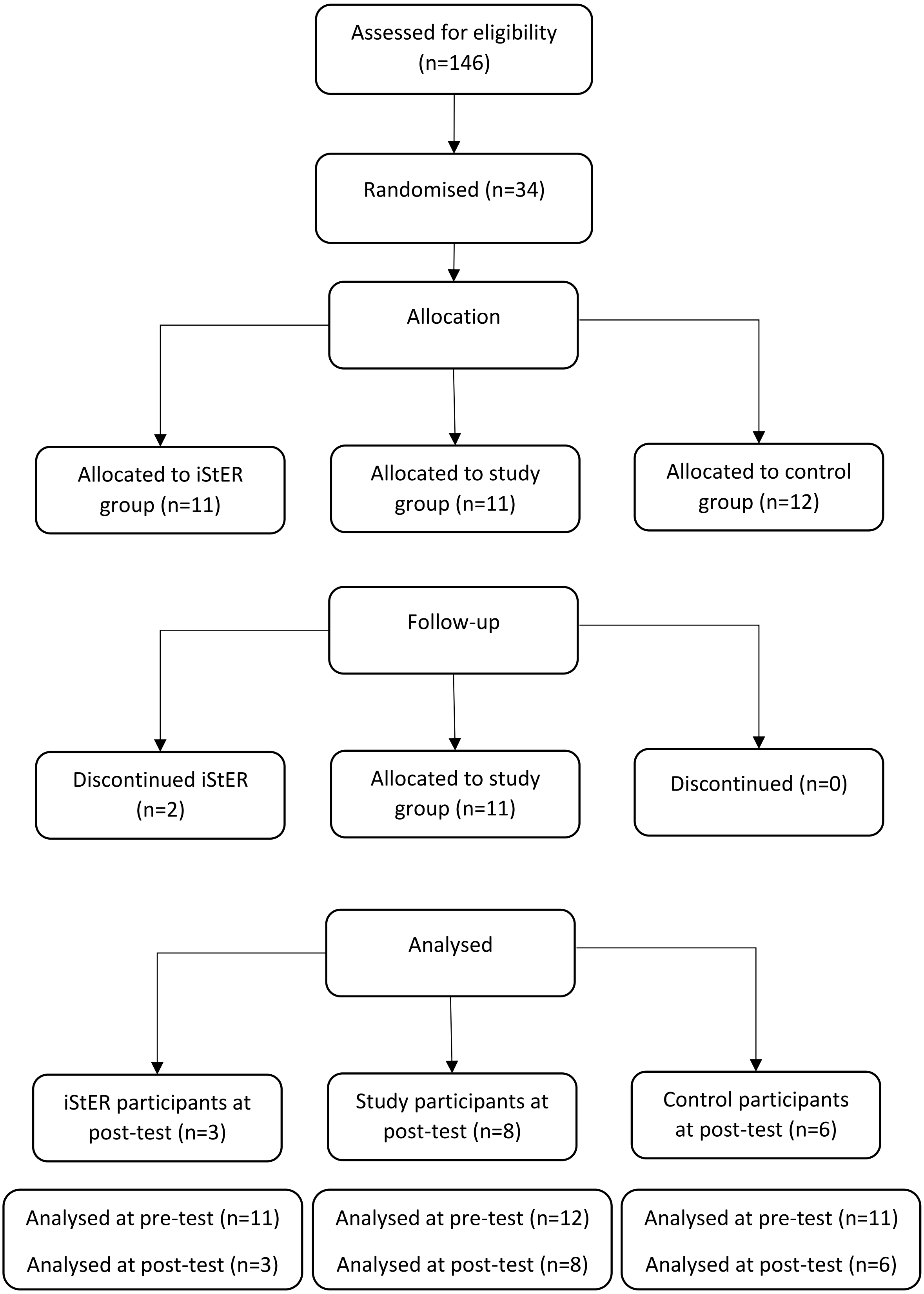


Figure 4. 1 *CONSORT flow diagram*

Implementation fidelity, adherence (attendance) compliance

Attendance to the weekly lunchtime sessions of the students in the iStER and chemistry groups is presented in Figure 4.2. In total, eleven students were randomly allocated to the iStER group and 12 students to the chemistry study group.

Figure 4. 2 *iStER and chemistry group student attendance to the weekly lunchtime study/revision sessions*

iStER resource packs

To assess student engagement with the iStER resource packs over the lunchtime sessions, we measured the number of iStER flashcards in students' study and review files at the end of each session. Engagement with iStER packs of each student in the iStER group is presented in Figures 4.3 to 4.9. The figures are presented in order by the number of sessions attended by each student (from most to least attended sessions). Figures 4.3 to 4.9 show the number of cards per file as well as the number of sessions attended by each student in the iStER intervention group. In the first session, there were 110 iStER flashcards in the study green file for all the students.

Figure 4. 3 *iStER intervention group student 32 engagement with the iStER resource packs*

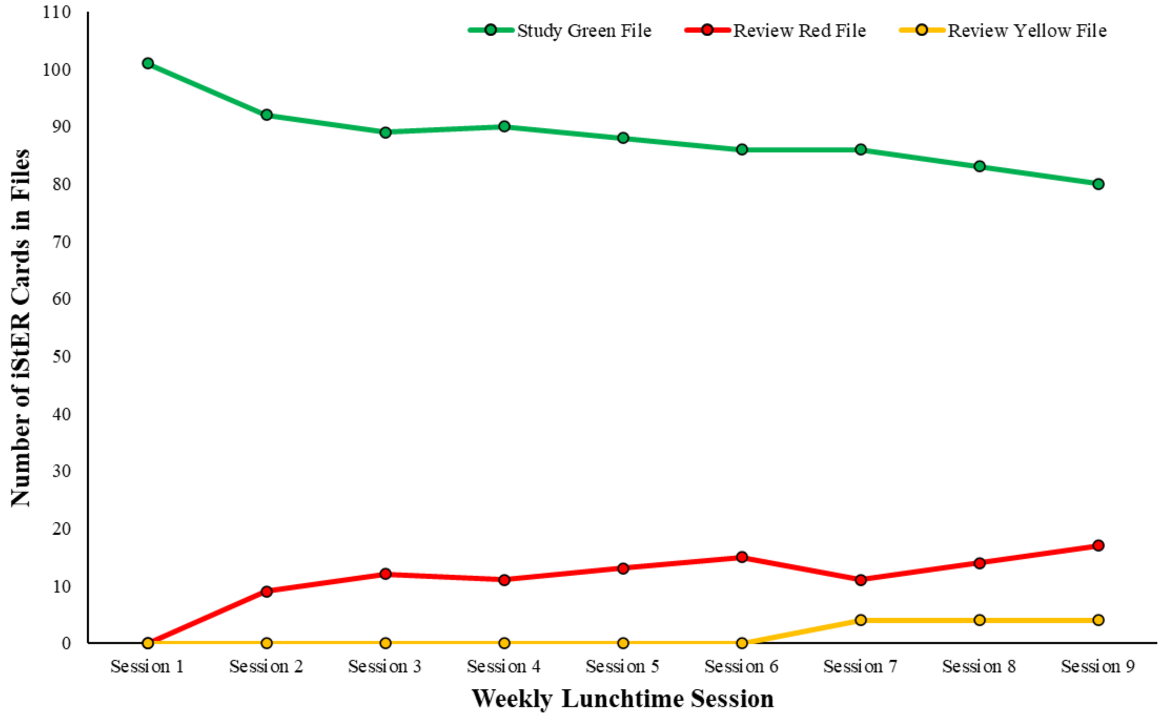
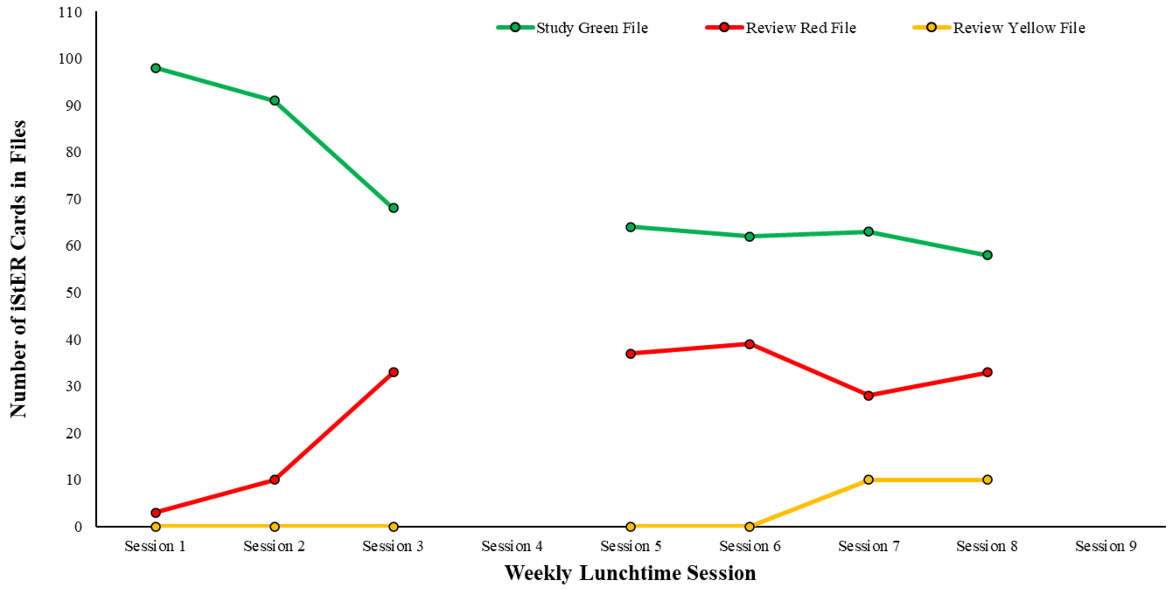
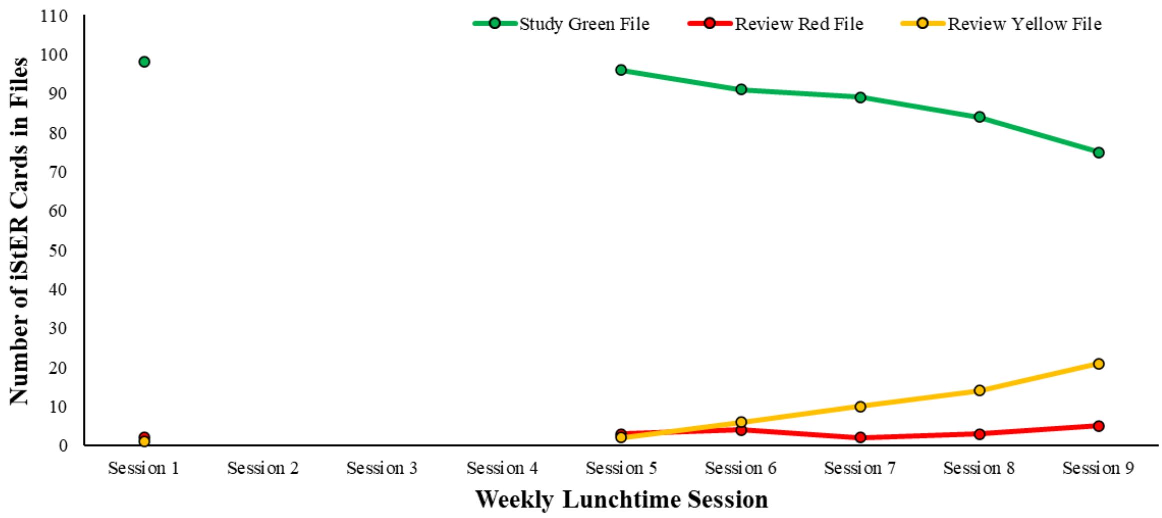


Figure 4. 4 *iStER intervention group student 30 engagement with the iStER resource packs*



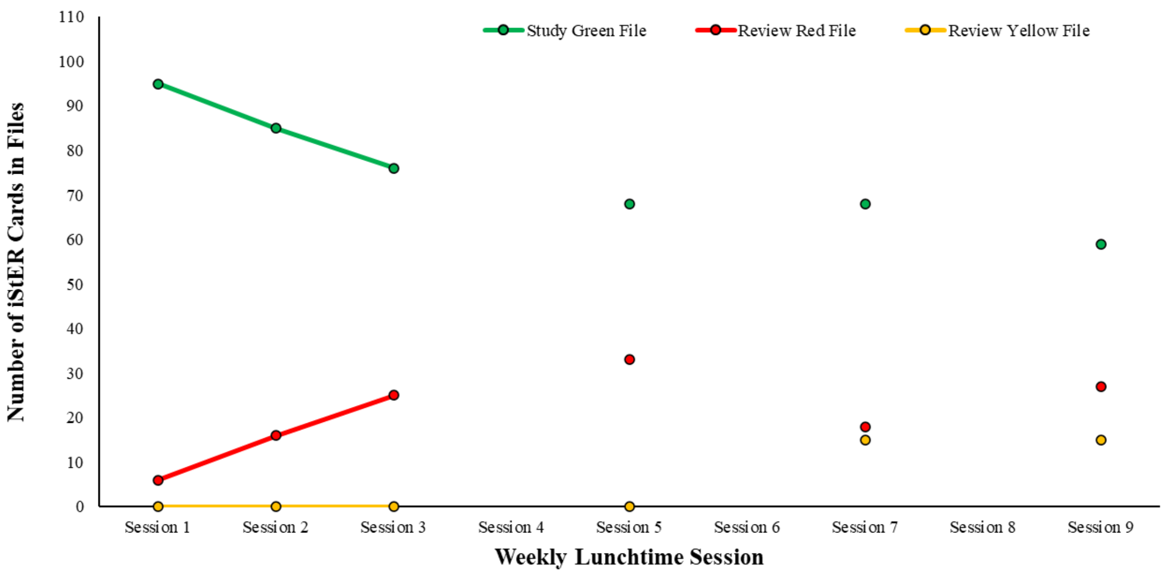
Note. We have presented the data from the sessions students attended, the gaps show the sessions students missed.

Figure 4. 5 *iStER intervention group student 28 engagement with the iStER resource packs*



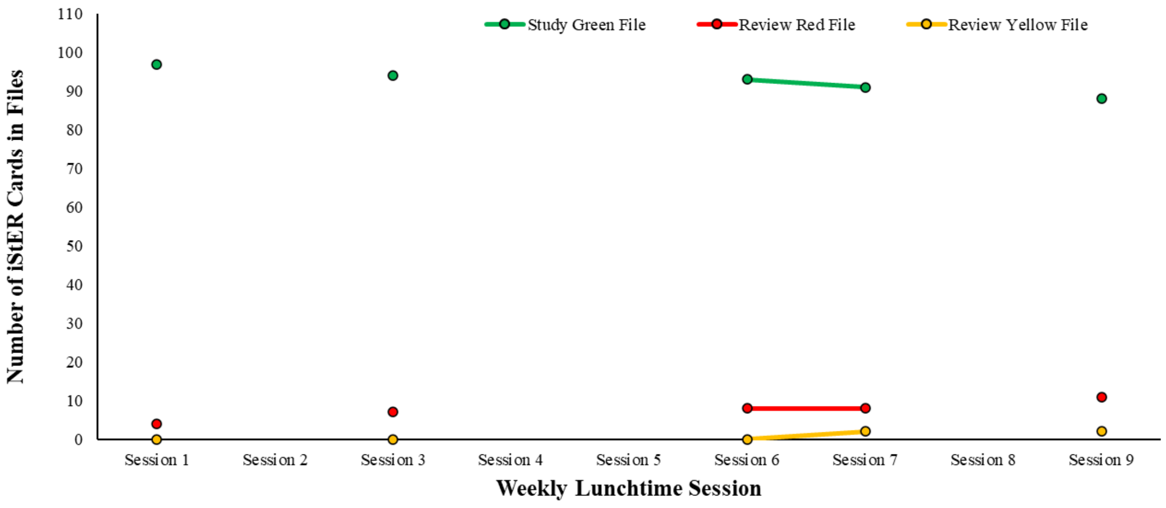
Note. We have presented the data from the sessions students attended, the gaps show the sessions students missed.

Figure 4. 6 *iStER intervention group student 29 engagement with the iStER resource packs*



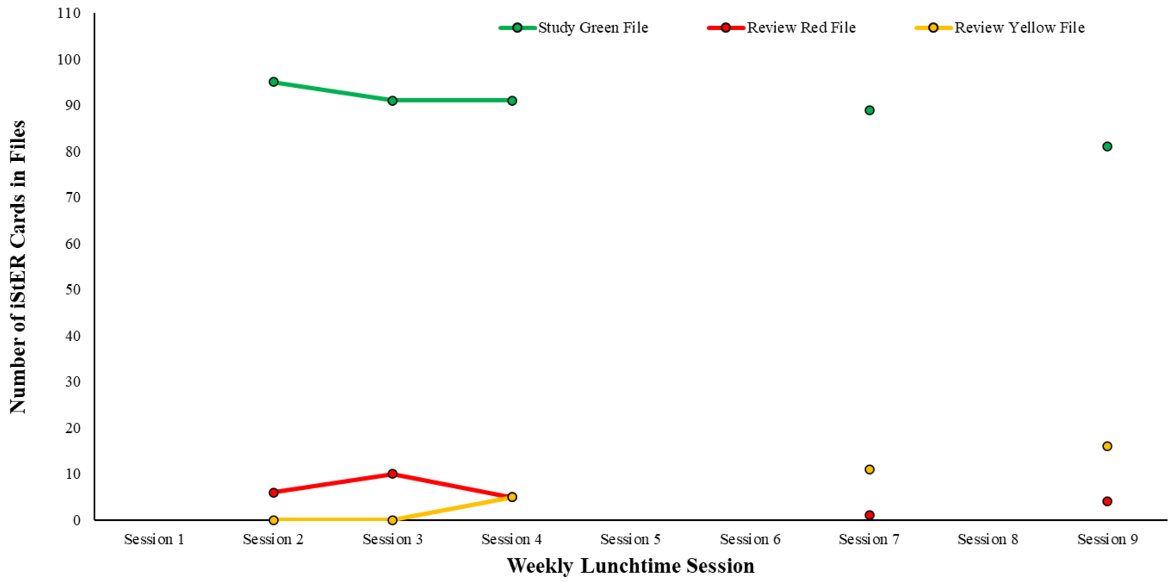
Note. We have presented the data from the sessions students attended, the gaps show the sessions students missed.

Figure 4. 7 *iStER intervention group student 33 engagement with the iStER resource packs*



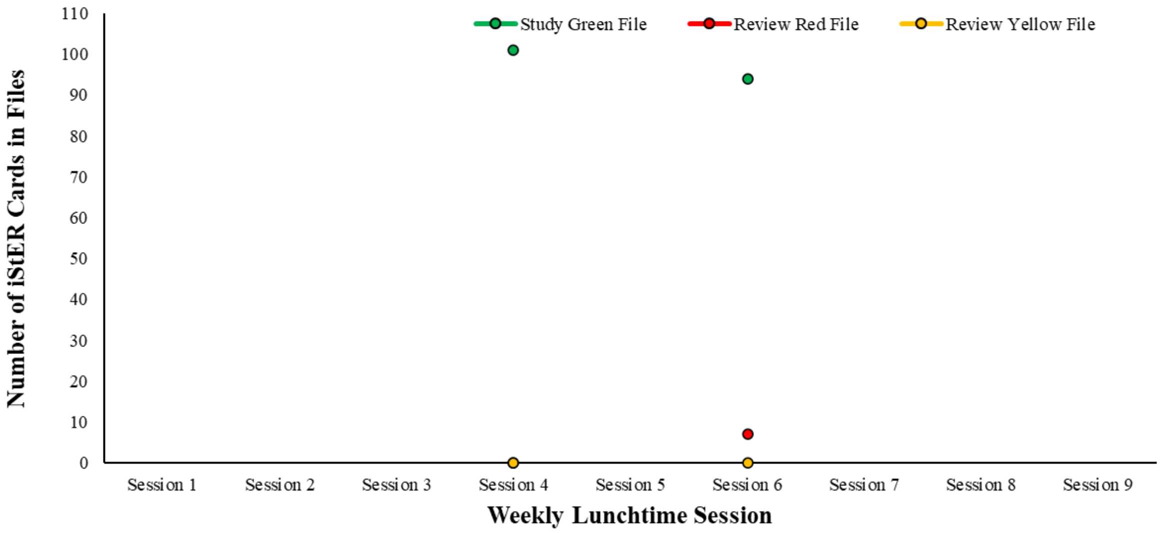
Note. We have presented the data from the sessions students attended, the gaps show the sessions students missed.

Figure 4. 8 *iStER intervention group student 25 engagement with the iStER resource packs*



Note. We have presented the data from the sessions students attended, the gaps show the sessions students missed.

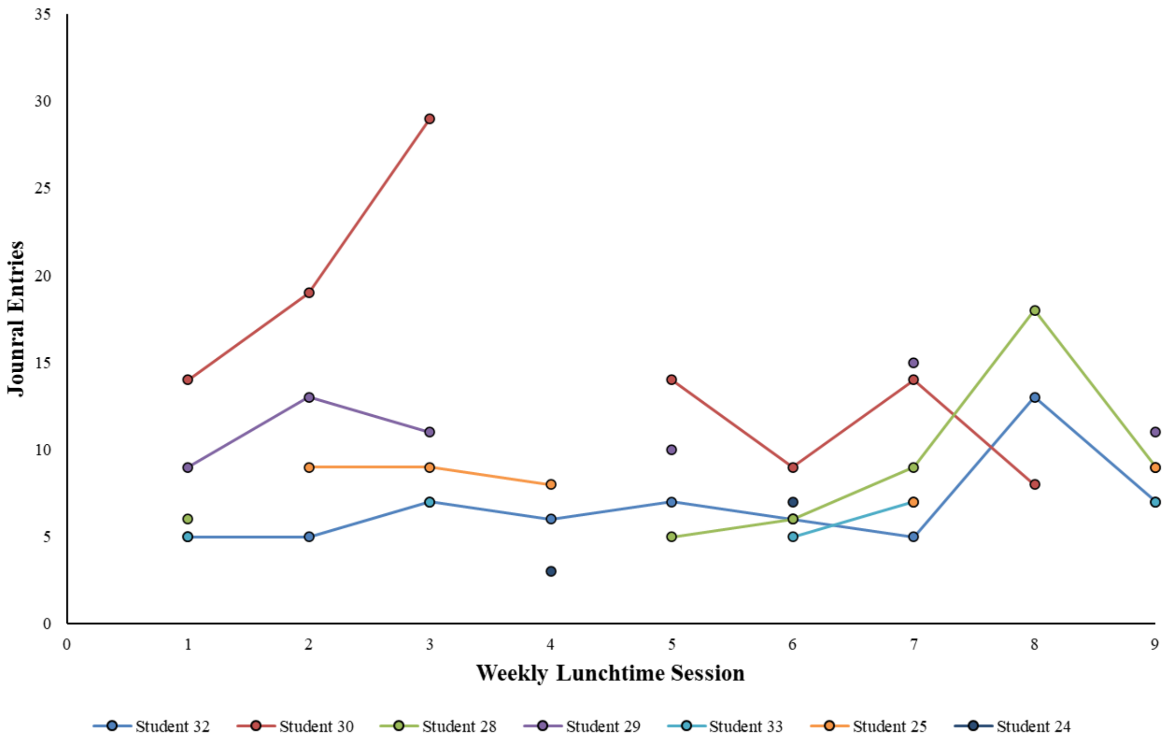
Figure 4. 9 *iStER intervention group student 24 engagement with the iStER resource packs*



Note. We have presented the data from the sessions students attended, the gaps show the sessions students missed.

To further assess the students engagement and motivation to use the iStER resource packs during the lunchtime sessions among students in the iStER group, we measured the number of entries made by students' in their iStER journals (i.e., number of iStER flashcard questions students attempted to answer and wrote the answer for in their journal). Engagement and motivation to use the iStER resource packs by students in the iStER intervention group is presented below in Figure 4.10. Figure 4.10 shows the number of entries made by the iStER intervention group students in their iStER journals (i.e., number of iStER flashcard questions students attempted to answer and wrote the answer for in their journal). The frequency scores for the number of entries made by the iStER intervention group students in their iStER journals are presented in Table P.1 (see Appendix P).

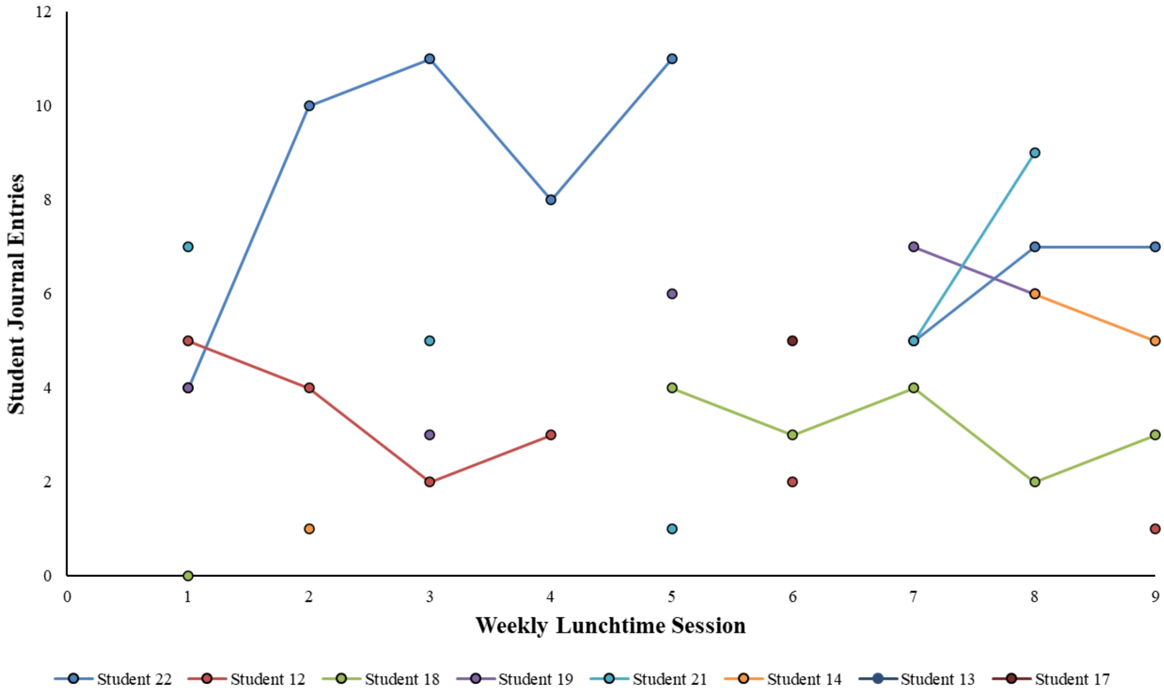
Figure 4. 10 *iStER intervention group student engagement with the iStER resource journals*



Chemistry study group resources

To assess student engagement with the resource packs over the lunchtime sessions among students in the chemistry study group, we measured the number of entries made by students who attended the sessions, in the journals at the end of each session (i.e., number of questions students would have attempted from the chemistry booklet). Engagement with the resource packs by the students in the chemistry group is presented below in Figure 4.11. Figure 4.11 shows the number of entries made by the chemistry intervention study group students in their journals (i.e., number of notes, number of questions students wrote down). The frequency scores for the number of entries made by the chemistry study intervention group students in their journals are presented in Table P.2 (see Appendix P).

Figure 4. 11 *Chemistry intervention study group engagement with the revision resource packs.*



Exploratory scores of students' chemistry assessment scores

Given that the present trial was a feasibility, we did not analyse students' assessment scores to evaluate any gains in students' chemistry content knowledge as a result of participating in the trial and between the three study groups. Moreover, there were limitations in the outcome data in the present study as the trial was stopped earlier (i.e., fewer students completing the post-test). In total seventeen students completed the post-test, three students from the iStER group, eight students from the chemistry study group and six students from the control group. Table 4.4 presents the median scores for students pre and post-test chemistry content scores by trial group. Table 4.5 presents the chemistry pre and post-test scores of the students in the control group, Table 4.6 presents the chemistry pre and post-test scores of the students in the chemistry study group alongside the number of sessions attended and Table 4.7 shows the chemistry pre and post test scores of the students in the iStER intervention group alongside the number of sessions attended.

Table 4. 4 *The median scores (IQR*) for students pre- and post-tests on measures of chemistry content outcome by trial group*

	Pre-test	Post-test
	m (IQR)	m (IQR)
iStER	24.0 (18)	27.0 (12)
Chemistry study	26.0 (19)	26.5 (25)
Control	23.0 (13)	23.5 (14)

Note. *IQR = interquartile range.

Table 4. 5 *Control group chemistry scores at pre-test and post-test.*

Participant	Pre-test score	Post-test score
1	19	
2	26	22
3	29	25
4	21	
5	28	30
6	34	34
7	12	
8	11	13

Participant	Pre-test score	Post-test score
9	24	
10	23	18
11	15	

Note. Chemistry scores were out of a total 56.

Table 4. 6 *Study group chemistry scores at pre-test and post-test, and number of sessions attended.*

Participant	Pre-test score	Post-test score	Number of sessions attended
12	27	27	6
13	24	26	2
14	33	31	3
15	25		
16	34		
17	46	39	1
18	16	11	6
19	14	15	5
20	15		

Participant	Pre-test score	Post-test score	Number of sessions attended
21	14	9	5
22	43	40	8
23	32		

Note. Chemistry scores were out of a total 56. In total there were nine sessions.

Table 4. 7 *iStER group chemistry scores at pre-test and post-test, and number of sessions attended.*

Participant	Pre-test score	Post-test score	Number of sessions attended
24	18		2
25	30		5
26	34		
27	21		
28	29		6
29	36	35	6
30	24	27	7
31	12		
32	25	23	9
33	10		5

Participant	Pre-test score	Post-test score	Number of sessions attended
34	9		

Note. Chemistry scores were out of a total 56. There was a total of nine sessions.

Discussion

The aim of the present study was to test the feasibility of using the iStER programme to help secondary students in Year 10 learn GCSE chemistry during lunchtime sessions. We designed this study as a feasibility randomised controlled efficacy trial to inform a later more definitive trial. Our primary objectives for the feasibility efficacy trial were: (1) to assess school and student acceptability of the intervention (2) to examine whether parents and carers would be willing for their child(ren) to be randomised to one of the trial arms; (3) assess how many students accepted the invitation to participate in research; (4) assess retention of students to lunchtime sessions by estimating attrition/retention rates; (5) assess student engagement with the iStER programme by estimating weekly session attendance rates, use of iStER resource packs; (6) to test study feasibility for lunchtime study and revision sessions for using the iStER programme (i.e., do lunchtime sessions for using the iStER during school hours work?). In addition the study aims to establish suitable procedures for delivering the iStER programme for a future definitive RCT. The aim was to establish the practicalities of delivering the iStER in school during supervised lunchtime sessions. In the following section, each of these efficacy trial objectives are discussed.

Recruitment, retention rates and attrition

The school science contact provided a list of eligible students. Although we planned to recruit 75 students, after one week only 36 parents/carers consented to their child(ren) participating in the study, signed forms were returned to the school science contact. Encouragingly, these parents/carers consented to their child(ren) being randomly assigned.

To help increase the number of students for the trial we postponed the trial start date to allow additional time for students to return outstanding consent forms. Despite our efforts, no more consent forms were returned. These data suggest that for a future larger evaluation trial we might need to employ a different recruitment method and allocate more time for parent/carer and student recruitment (i.e., allow time to send multiple reminders). Furthermore, we planned to have two pre-testing sessions, this was to allow students who returned consent forms in the second week and any students that were absent on the first day of the pre-test the opportunity to complete the pre-tests. A longer recruitment period would be helpful to send reminders to parents and carers to encourage them to participate. The school science contact was absent during the week of the second pre-test and therefore we were not able to make further arrangements within the school for the four students who were absent on the day of the pre-test, or returned forms later, to complete the pre-test. Given that the initial timescale for the trial was reduced to five weeks from six weeks, we decided to start the feasibility efficacy trial with the 34 students who had completed the pre-test during the first testing session. We decided that the four students that were absent on the day of the first pre-test and any students who return signed consent forms after this would receive the iStER learning resource with the students in the control group and chemistry study group. For a larger trial it would be beneficial to have an additional science contact within the school.

In addition to obtaining parental and carer consent for the present trial we also obtained student assent prior to students completing the pre-test. One student declined to participate in the study on the day of the pre-test. Moreover, two students in the iStER group withdrew from the trial on the day of the iStER training session. There was a retention rate of 81.82 per cent in the iStER group, and 100 per cent in the chemistry study group. The findings are encouraging in terms of one of the trial objectives.

Implementation fidelity, adherence (attendance)

All students in the iStER group received the intervention (iStER training and resource packs), adherence to the weekly lunchtime study/revision sessions of the trial was low with only one student attending the proposed three sessions per week. One of the reasons why some students were not able to attend all three sessions was because of other commitments during lunchtime hours. However, the overall attendance to the weekly lunchtime sessions of the trial among students in the iStER intervention group was 77.78 per cent. These data suggest that students in the iStER intervention group were keen to study/revise chemistry independently during their lunch hours and suggests that there is a demand among secondary students for study/revision learning resources. These are promising findings for a larger evaluation trial.

The main outcome measures were successfully implemented with all the students. Given that the current study was a feasibility efficacy trial and was stopped earlier due to the COVID-19 pandemic we did not assess change, and particularly whether the iStER intervention group made significant gains on their chemistry scores (i.e., content knowledge). Only three students in the iStER intervention group completed the post-test. Focusing on individual students, one student in the iStER intervention group scored higher in the post-test. The chemistry scores of two of the students in the iStER intervention group were slightly lower in the post-test assessment compared with the pre-test. Adherence to the proposed level of intervention intensity (3 sessions per week) was not possible. This was a limitation of the current study. In school settings, additional activities during lunch hours meant some students were unable to find time to attend the lunchtime session to use the iStER resource packs. Consequently, intervention intensity varied between students in the iStER intervention group. Due to the lower number of students, we did not explore the correlation between the number of session(s) a student attended and any improvement students might have made at post-test. An additional limitation of organising the efficacy trial during lunchtime was some students wanted to bring their friend(s) along to the session.

We recognise that intervention outcome is important, however, our feasibility efficacy trial findings suggest that there is a demand for support with study/revision among secondary students. The overall attendance among students in the chemistry study group was 66.67 per cent for the lunchtime sessions. This was despite students in this group not receiving the iStER packs, instead students were given the chemistry content in a booklet format (see Appendix M) to study using their usual/own learning strategies. These data suggest that students in the chemistry study group that did not receive the iStER learning resources were keen to study/revise chemistry independently during their lunch hours and suggests that there is a demand among secondary students for study/revision learning resources. These are promising findings for a larger evaluation trial.

To further measure fidelity of the programme, we assessed student engagement with the iStER resource packs. To help assess this, we collected data at the end of each session from students iStER resource packs on the number of iStER flashcards in each file (i.e., green study file, red review file, yellow review file) and on the number of entries made by students in their iStER journals (i.e., number of iStER flashcards students attempted), instead of students self-reporting this data. The data on all individual students in the iStER intervention group who attended the lunchtime sessions indicated the students were engaging with the iStER resources and made progress with the iStER flashcards. Over the course of the efficacy trial the number of cards in students study green file decreased with attendance to the lunchtime sessions. The number of cards in the review files (i.e., red, yellow) decreased with attendance to the lunchtime sessions. We used iStER journals to ensure students were using retrieval practice to learn the iStER flashcards (i.e., students were required to first read a question, before turning the iStER flashcards to see the answer students had to write down in their journal). All students in the iStER intervention group who attended the sessions made entries in their journals, suggesting that students were engaging with the resources. The use of files based on the Leitner system to ensure students do not progress before learning the content on the cards in the study green file allows students to self-pace and help ensure students do not avoid the cards they might not know well and practise the cards they know well. Given the small number of students in the current trial it was feasible to collect this data. For a larger scale, monitoring of these aspects is important. For a future larger scale intervention implementation, additional resources would be needed. However, it might involve additional costs and researcher time on visiting schools to collect the data. For a future trial larger scale sixth form students could be trained to support collecting data on students progress.

Recommendations for a future RCT

Our current study was a feasibility efficacy trial randomised at the individual student level. We recruited one secondary school and separated students individually to one of the three trial arms (i.e., iStER intervention group, chemistry study group, waiting list control group). Given that the sessions were organised outside of timetabled lessons, it was possible to separate students individually for the purpose of our trial to eliminate potential contamination through peer to peer learning (students receiving the iStER resource packs sharing these with students allocated to the chemistry study group, control group). This was successful, however, to control for potential contamination the iStER resource packs were collected by the research student at the end of each session. The presence of a research student introduced an additional confound (i.e., researcher), for which reason we had to employ an additional group for the current trial (i.e., chemistry study group). However, the feasibility of individual randomisation in a larger, full-scale evaluation is important to consider because of the potential for contamination as well as additional costs in terms of resources and researcher time spent on an additional trial group. Moreover, implementation of an individually randomised trial was feasible partly due to the small number of students who received the intervention. An alternative approach to use in applied educational settings is a cluster randomised design. In the cluster RCT the school or class will be the unit of study with intervention delivered to an entire class or even school (Connolly et al., 2017). In fact, in education research trials the clustered RCT design is the more widely adopted design because students are grouped in classes as part of their daily school activities (e.g., lessons), therefore this minimises any unnecessary class disruption and because often it is practically not possible to separate students individually for the purpose of a trial during timetabled school lessons. In a future evaluation of the iStER intervention using a clustered RCT design, randomisation would be at the school level. Schools will be the unit of study with intervention delivered to schools. Schools will be recruited on the basis that they would be allocated to receive the iStER intervention or to a waiting list control group in which they continue to deliver any usual study/revision provision and students continue to attend lessons as usual, until the end of the trial when control students would also receive the intervention.

We have mentioned above that a limitation of the current trial was adherence to the proposed level of weekly sessions as well as students wanting to bring their friend(s) to sessions. Another approach using a clustered RCT design is to deliver the iStER intervention during timetabled lessons, either at the start or end of lessons. In such an evaluation of the iStER intervention using a clustered RCT design, randomisation would be at the school level. This would be an efficacy trial. Given that the current efficacy trial assessed the feasibility of lunchtime sessions to deliver the iStER programme, any future trials in which the iStER intervention is delivered at a different time would also be an efficacy trial before scaling up to an effectiveness trial.

Overall, in the current trial we have generated data to inform a future definitive larger trial of delivering the iStER intervention during weekly lunchtime sessions. We have demonstrated that it is possible to conduct studies with strong experimental design with secondary students in schools. We have gained experience in delivering the iStER programme and have established the practicalities of delivering the iStER intervention in school during supervised lunchtime sessions. There are two possible next steps in our research. One option is to design a clustered RCT to deliver the iStER during lunchtime sessions. This programme is ready to be scaled to an effectiveness trial. Given the limitations in terms of delivering the iStER intervention during lunchtime sessions (i.e., adherence), an alternative option for us might be to first explore lesson time for delivering the iStER intervention using a clustered RCT design. This programme would be an efficacy trial. Importantly, our trial has shown that there is a demand for evidence-informed study/revision learning resources to support independent learning among both schools and students.

Chapter 5: Discussion

Preface

This chapter provides a summary on the overall findings of the thesis, including the implications and recommendations for schools, school improvements professionals and policymakers. We highlight the need for ongoing research into support with independent learning in Wales and discuss the challenges of undertaking school-based research.

Overview of thesis aims

There is a need to improve the standard of science outcomes in secondary schools in Wales as repeatedly highlighted in the work undertaken by PISA and Estyn (OECD, 2007; 2010; 2014a; Estyn, 2017). Given the importance of science, it is crucial that evidence-informed interventions are identified and used. In 2021, the Welsh Government's National Strategy for Educational Research and Enquiry (NSERE) was launched to help ensure educational provisions are focused along more evidence-informed lines (Welsh Government, 2021). The recent COVID-19 pandemic has highlighted the need for students to have strong independent learning skills (Waters-Davies et al., 2021; Department for Education, 2022). A recommendation proposed from the findings of the research studies on the impact of the pandemic on the Welsh Education System for 2020 was that the new curriculum should consider the importance of independent learning (Welsh Government, The National Strategy for Educational Research and Enquiry, July 2021). The use of evidence-informed learning strategies for independent learning (i.e., study and revision) can play an important role in helping secondary students improve learning in science and develop strong independent learning skills.

In 2013, Dunlosky et al. (2013) evaluated ten commonly used learning strategies by student populations and provided a useful utility ranking of the learning strategies. The findings of Dunlosky et al. (2013) and associated research in cognitive and educational science have important implications for students' independent learning practice. There is however a distinct lack of research into what learning strategies are currently being taught in schools and what learning strategies students' use for independent learning. The studies in this thesis have, for the first time, provided an insight into secondary school students' use and understanding of common learning strategies for independent learning for science in the UK.

The broad aim of the thesis was to evaluate the use of evidence-informed learning strategies for improving secondary school students' learning in science. As a first step, it was important to first evaluate what learning strategies were being promoted in secondary schools and what strategies students’ were using to study/revise for science. In the first survey study, we explored secondary school science subject leaders’ understanding and recommendations of learning strategies to help students revise for science examinations (Chapter 2). We conducted a cross-sectional survey with 35 science subject leaders teaching in secondary schools in North Wales. The second study was a population-based survey with secondary students and evaluated students’ use and understanding of learning strategies for independent learning (Chapter 3). In total, 29 secondary schools in North Wales participated in the survey, and we obtained responses from 385 secondary students in participating schools. The third study in this thesis represents a project that extended our work in the first survey we conducted to investigate the impact of COVID-19 on the study practice of secondary students. Guided by our survey findings with teachers and students, the next step in the PhD involved developing a learning resource called Improving Standards through Effective Revision (iStER) programme to educate secondary students about the most effective learning strategies and improve their independent learning skills. The final study assessed the efficacy of a feasibility randomised controlled trial of lunchtime study/revisions sessions to learn GCSE chemistry using the iStER learning resource. In the following section, Chapters 2, 3 and 4 are discussed in more detail together with the strengths, limitations and future directions for research for each study.

Chapter 2

The use of evidence-informed learning strategies has become an important subject both in teacher continuing professional development (CPD) circles and also researcher-driven websites and fora aimed at getting evidence into education (e.g., The Learning Scientists [https://www.learningscientists.org/], Unleash the Science of Learning [https://www.retrievalpractice.org/], Bringing cognitive science to the classroom [https://cogscisci.wordpress.com/]). School teachers are an important source of information and guidance for students as they prepare to learn and revise for examinations. To increase the use of evidence-informed learning strategies in schools, it was important to understand what learning strategies teachers are promoting and what they understand about effective learning strategies. Studies with instructors at all educational levels showed that educators promote both less and more effective learning strategies and have a moderate understanding about evidence-informed learning strategies (McCabe, 2018; Piza, 2018; Morehead et al., 2016; Perry et al., 2021; Surma et al., 2022).

To date, only two of the studies involved a survey with school teachers on their recommendation and understanding of evidence-informed learning strategies (Perry et al., 2021; Surma et al., 2022). There was no research in the UK that had evaluated the learning strategies promoted by teachers in secondary schools. It was important to know which learning strategies are currently being promoted by teachers in secondary schools. We conducted a cross-sectional survey with science subject leaders in North Wales, to evaluate the learning strategies subject leaders promote in schools to help students revise in preparation for science examinations. Our survey findings have for the first time provided an insight into secondary school science teachers' recommendation and understanding of common learning strategies. Our results showed that teachers in schools encourage the use of a variety of common learning strategies including both low and high utility strategies, and have a moderate understanding about the utility of learning strategies. These findings align closely with the outcomes of previous studies in university and school settings (McCabe, 2018; Piza, 2018; Morehead et al., 2016; Perry et al., 2021; Surma et al., 2022).

Importantly, our findings suggest that many teachers, trainees, newly qualified and more experienced teachers would benefit from an improved understanding of evidence-informed learning strategies, and how to better support learners use these strategies. There is a need for ongoing research into the learning strategies promoted by teachers in secondary schools, as well as teachers' understanding of evidence-informed learning strategies.

Strengths, limitations and future research

We acknowledge some limitations in our survey with secondary teachers presented within Chapter 2. There was a typographical error on the response scale for survey item one, for this reason we decided not to administer the survey electronically to any subject leaders that were not present at the meeting to increase the survey response rate. Nonetheless, this study achieved a response rate of 64.8%. Despite these limitations, this is the first study to report on secondary teachers' recommendations and understanding of a variety of common learning strategies to help students with independent revision of science from a sample of teachers in mainstream schools in the UK. However, as the survey focussed exclusively on science subject leaders, future studies should also focus on both trainee and more experienced science teachers' recommendations and understanding of learning strategies.

Although we have made a start on developing this evidence, there is clearly more research needed, especially considering we only focused on science learning. Additionally, other curriculum areas rely less on formal examinations, and it would be interesting for future research to investigate how students best prepare for a variety of different curriculum areas. This is especially important within the context of reform in Wales and the move towards a focus on diverse forms of assessment methods.

Chapter 3

One of the main aims of this research was to evaluate students’ knowledge and use of learning strategies in secondary schools. Much of the earlier research into students’ use and understanding of learning strategies have been with university students and report findings from surveys using non-probability sampling methods (i.e., convenience sampling). To date, only the study by Agarwal et al. (2014) and Dirkx et al. (2019) involved a survey with secondary school age students. However, a limitation of the study by Agarwal et al. (2014) was that the authors collected responses from students at the end of an experimental study on retrieval practice, which might have influenced students’ responses to the survey questions. Moreover, the studies by Agarwal et al. (2014) and Dirkx et al. (2019) used convenience sampling and these studies did not assess secondary students’ understanding of learning strategies. There was still no research using probability sampling methods and it was still unclear why students’ might rely on less effective learning strategies (i.e., lack of awareness about more effective learning strategies, lack of knowledge about the effectiveness of the learning strategies they frequently use). Although the studies by Agarwal et al. (2014) and Dirkx et al. (2019) for the first time provided an insight into secondary students’ use of learning strategies, these studies were based on samples of secondary students in the US and the Netherlands. There was still an absence of empirical research into secondary students' learning practice in the UK. It was important to close this research gap, and to collate evidence that would help inform the next steps in the PhD, and inform our project partners guidance to schools to help students access and use more effective learning strategies.

We conducted a population-based survey with secondary students in North Wales (Chapter 3; Study 1), and obtained responses from 385 secondary students in the 29 participating schools. Our results indicate that students predominantly rely on less effective learning strategies for independent study and revision (i.e., making notes [summarising], repeatedly reading information, highlighting [or underlining information]) and do not realise some of the strategies they most frequently use are less effective approaches. The findings here align closely with the outcomes of previous studies which found that secondary students relied on less optimal learning strategies (Agarwal et al., 2014; Dirkx et al., 2019), and suggest that students would benefit from receiving information about training in using more effective learning strategies such as retrieval and spaced practice to help equip students with independent learning skills. Importantly, this information helped us to understand that there is a need to develop further guidance to improve students' independent learning skills to enable them to make more effective use of their independent study and revision time in preparation for examination, and this led to the development of the improving standards through effective revision (iStER) learning resource presented within Chapter 4.

In 2021, we were successful in obtaining a research grant from the Welsh Government to extend our PhD survey work, to explore secondary school students' study practice during the COVID-19 pandemic (Appendix E). In the latter part of Chapter 3 we discussed the findings and implications of this study (Study 2). In Wales there has been some research surrounding the influence of the pandemic on the independent learning of students in secondary and further education settings (i.e., sixth forms, colleges) (Mylona & Heledd, 2021; WISERD, 2020). Research on the impact of the pandemic on students' learning did not explore students' independent learning skills, nor strategies for completing independent work using online and/or offline learning resources during the pandemic. There was also no published research assessing secondary learners' confidence in using digital learning platforms. It was important to close this research gap and collate reliable information on the independent learning practice of students as well as students' confidence pre and post pandemic to inform policy responses to support learners with independent learning and study skills post-pandemic. Through the use of survey research methods we designed a cross-sectional survey with students aged 14–15 and 16–17 years in mainstream middle and secondary schools in Wales. We used a multistage clustered sample design for a sample selection.

Despite the need for students to work more independently during the periods of school closures, we found similar results to our previous survey with secondary school students presented in Study 1 and no improvement in the use of more effective learning strategies by learners. Our results showed that students reported using both less and more effective learning strategies whilst learning at home. Our data also suggest that students' still do not have an accurate understanding about the effectiveness of some common learning strategies, suggesting that students' use and understanding of learning strategies has not changed significantly since the start of the COVID-19 pandemic. This highlights the need for schools to continue to improve awareness about effective learning strategies and resources in Wales.

Strengths, limitations and future directions

In Chapter 3 we outlined some limitations of Study 1 with secondary school students. These included methodological weaknesses. In survey item three, students were required to report and rate the three learning strategies they most frequently used for study/revision. As a result, the total number of students rating each learning strategy was small and the mean ratings for the students' perceived effectiveness of the various learning strategies may not be statistically significant. Also, we do not have information on students' opinions of other study strategies that they might use less frequently. Despite these limitations, this is the first study to report on secondary students' study and revision habits from a representative sample of 14-15 year old students in mainstream schools in the UK. As our responses included a stratified, random sample of learners from different ability groups, the results are less likely to be biased towards over- or under-reporting due to students who were more- or less interested in study and/or revision. Our findings are also less likely to be distorted due to chance under-representation of student groups. Also, our findings are based on a more representative methodology and are, therefore, likely to generalise more broadly to students in other regions of the UK where students follow very similar science qualifications in comparable school settings.

One of the main limitations of the second study with secondary students was the low response rate (Appendix E). Whilst a higher response rate would have enhanced our findings, we were constrained by the limitations of school exam periods and school' capacity to engage. As a result we were unable to extend the survey timescale to allow us to gather additional responses. Despite this limitation, the Study 2 is the first study to report on the influence of the pandemic on secondary students' independent learning practice.

Although the second study is based on a small sample of students, we obtained more information on students' independent learning practice using a modified version of the ERaSSQ survey with students. The ERaSSQ had been modified following peer review in an academic journal and to reflect appropriate changes in learners' education that relate to the COVID-19 pandemic. We asked students' to rate the effectiveness of all common learning strategies to provide an insight into what students understand to be the most- and least-effective strategies. We now have information on students' opinions of other study strategies that they might use less frequently. In addition to investigating 'what' learning strategies students' were using we also examined 'why'. We explored where students' knowledge about learning strategies and resources came from (e.g., parents/carers, schools, peers). We also obtained information on students' confidence when using digital learning platforms, and their confidence towards independent learning skills and activities. Further research should now: (1) focus on the practical barriers to secondary students' use of effective learning strategies; (2) explore whether students' use of learning strategies predicts their actual learning outcomes; and (3) explore students' study practice using mixed methods designs (quantitative and qualitative).

Chapter 4

Our survey findings suggest that teachers promote a combination of learning strategies and students are not making use of the most effective learning strategies for independent learning. However, students are keen to learn about and use more effective learning strategies. To help students use more effective learning strategies and improve their independent learning skills we developed a learning resource to help students apply two higher utility strategies to improve their learning of science. We also wanted to test the feasibility of using the programme with learners in school.

Cognitive science is being used increasingly to inform interventions, practice and policy in education (e.g., Kirschner & Hendrick, 2020). Research suggests that two strategies, retrieval practice and spaced practice, are more effective in helping learners achieve educational outcomes (Agarwal et al., 2021; Dunlosky et al., 2013; Karpicke & Roediger, 2006). Although there are learning resources available to help students in the application of effective learning strategies (e.g., Seneca [https://senecalearning.com/en-GB/], Quizlet [https://quizlet.com/en-gb]), more support is needed to aid learners in the application and transfer of effective learning strategies (e.g., Biwer et al., 2020a; Biwer et al., 2020b; McDaniel & Einstein, 2020; Oakes and Griffin, 2016). Some existing learning programmes make use of effective learning strategies that are embedded in the software algorithm of the resource, but these are not explicitly taught to students within the programme interface. Importantly, the survey findings presented within Chapters 2 and 3 indicate that in addition to educating students about effective learning strategies, it is important to teach students about proactive independent learning, the importance of effort (i.e., investing time), as well as the relative utility of other commonly used learning strategies. We developed the iStER learning resource to address these important points.

The iStER learning resource is aimed at secondary school students aged 14–16 years, and is designed to inform students about evidence-informed learning strategies, and to raise awareness about, and normalise, independent learning habits (i.e., study/revision). The programme furthermore provides a system and materials and resource packs to help students to apply effective learning strategies (i.e., spaced practice and retrieval practice), using evidence informed approaches (i.e., Leitner system) to organise their independent learning. The iStER learning resource teaches students about proactive independent learning, effort (i.e., investing time for independent work), how we learn, the utility of common learning strategies, and how effective learning strategies help us to learn and remember information (i.e., provides students with the knowledge about proactive independent work and about learning strategies). In addition to helping students acquire knowledge about proactive independent work and learning strategies, to promote the use of effective learning strategies, we developed iStER resource packs which contain materials and evidence-informed approaches to help students develop the habit of independent work and practically apply effective learning strategies for their independent study and revision. iStER provides a system to help students organise their learning resources and time.

In Chapter 4 we also report an individually randomised feasibility controlled trial of a lunchtime study/revision programme to learn GCSE chemistry using the iStER learning resources. There have been very few studies that have used robust experimental designs (i.e., randomised experimental designs) to investigate the effectiveness of learning strategies on students' learning. In the UK, a study by Feddern et al. (2018) evaluated the effectiveness of an online learning resource called Seneca Learning (https://senecalearning.com/en-GB/) with secondary students using a cluster randomised controlled trial. However, the study by

Feddern et al. (2018) was an effectiveness trial. In contrast, we designed a feasibility randomised controlled trial of a lunchtime study/revision programme to learn GCSE chemistry using the iStER learning resource with secondary students. Our trial was designed to test the feasibility of key aspects such as programme delivery and study design. Our feasibility trial was at the efficacy level (Owen et al., 2022).

The programme ran for five weeks and was delivered by the research student. In total 34 students were recruited for the trial, and were then randomly allocated to one of three trial arms; the intervention (n = 11), chemistry study (n = 12) or waiting list control (n = 11) groups. Our primary objectives in this phase were to test the feasibility (recruitment and retention rates, completion rates, attendance, adherence to intervention) of undertaking an experimental study to evaluate the impact of using the iStER programme during lunchtime study/revision sessions to learn GCSE chemistry. Importantly, answers to our feasibility trial would inform decisions as to whether the program is ready to be scaled to a larger efficacy trial to test if it works under controlled conditions with a strong design. Then, if results from this are positive we would move to effectiveness studies (i.e., to test if it works under less controlled conditions without researcher support, for example with teachers delivering). We collected important data to inform a definitive evaluation trial (i.e., recruitment and retention rates, completion rates, attendance, adherence to intervention). After completing training and pre-tests, we had to stop the trial earlier than planned in March 2019 due to school closures caused by the COVID-19 pandemic. Initially we planned to recruit 75 students, however were able to recruit 34 for the feasibility trial. We were constrained by the limitation of time and as a result we were unable to extend the recruitment period to allow us to send reminders to parents and carers to encourage them to participate. These data suggest that a longer recruitment period would be helpful for a future definitive trial. Parents and carers of identified students consented to random student allocation. This is an encouraging finding given that randomisation is an integral part of RCTs.

Our results showed the overall attendance to the weekly lunchtime study sessions of the trial among students in the iStER intervention group was 77.78 per cent, suggesting students were keen to study/revise chemistry independently during their lunch hours and that there is a demand among secondary students for study/revision learning resources. These are promising findings for a larger evaluation trial. However, adherence to the proposed level of intervention intensity (3 sessions per week) was not possible. This was a limitation of the current study. In school settings, additional activities during lunch hours meant some students were unable to find time to attend the lunchtime session to use the iStER resource packs. The data on all individual students in the iStER intervention group who attended the lunchtime sessions indicated the students were engaging with the iStER resources. Over the course of the trial the number of cards in students' study file (i.e., green file) decreased with attendance to the lunchtime sessions, and the number of cards in the review files (i.e., red, yellow) decreased with attendance to the lunchtime sessions. The feasibility results from this small-scale efficacy trial are promising findings for a future trial. The next step in this research would be a strongly designed efficacy randomised controlled trial to assess whether the iStER earning resources is effective in controlled conditions.

Implications of the thesis study findings

The findings presented in Chapters 2 and 3 suggested that students would benefit from receiving training in effective learning strategies. Our surveys also indicated that both students and teachers were interested in students receiving more information about effective learning strategies to help students with independent learning. To date, our findings have been used to develop the iStER learning resource to help secondary students learn science.

The surveys presented within Chapters 2 and 3 have important policy and practice implications for both schools, school improvement professionals and also providers of initial teacher education. For providers of initial teacher education it is important that course programmes equip early career teachers with the relevant knowledge and understanding about more effective learning strategies. Our results also suggest that secondary school teachers would benefit from receiving training about effective learning strategies to help students study and revise more effectively. Importantly, findings from our survey with science teachers (Chapter 2) indicate that secondary teachers would welcome more information and guidance about effective learning strategies, and nearly all the teachers in our survey (97.1%) reported that they were keen to receive information about effective learning strategies. In addition, almost half (48. 5%) reported that they did not have access to relevant information on effective learning strategies.

Importantly there is also a demand for more information on effective learning strategies among secondary school students. In Study 1 with secondary students presented within Chapter 3 we found that students want more information about evidence-informed learning strategies to help them study/revise effectively in preparation for exams. In fact 81.7 per cent reported that they were interested in receiving information about effective strategies and 96.1 per cent believe students should be provided with information on effective learning strategies. In the second study with students presented within Chapter 2 we found similar results to our first study. In Study 2, of the respondents, 71.1 percent reported that they were interested in receiving information about effective learning strategies and resources to help them with independent learning. Importantly, 82.5 percent of students reported that they should be provided with information about effective learning strategies and resources to support their independent learning in the event of any future school closures and/or online learning.

The purpose of our feasibility trial was to test lunchtime sessions for using the iStER programme as well as test the feasibility of a future trial. Interestingly, our feasibility trial study also showed that there is a demand for support with study/revision among secondary students. Our results showed that it was feasible to use the iStER programme with secondary students and that it is feasible to carry out a future RCT to evaluate its efficacy. The overall attendance to the weekly lunchtime study sessions of the trial among students in the iStER intervention group was 77.78 percent, suggesting students were keen to study/revise chemistry independently during their lunch hours and that there is a demand among secondary students for study/revision learning resources. Interestingly, the overall attendance to the lunchtime sessions among students in the chemistry study group was similar (66.67%), despite the students in the chemistry study group not receiving the iStER learning resource.. These data suggest that students in the chemistry study group that did not receive the iStER learning resources were keen to study/revise chemistry independently during their lunch hours and suggests that there is a demand among secondary students for study/revision learning resources. These are promising findings for a larger evaluation trial and suggest it is feasible to recruit to both an intervention and control arm. Importantly, our trial has further shown that there is a demand for evidence-informed study/revision learning resources to support independent learning among both schools and students.

Dissemination and next steps

The most important next step for our work is the need for a strongly designed efficacy trial using our feasibility trial findings (Chapter 4).

The findings for our thesis studies within Chapters 2, 3 and 4 have been shared with our project partner in the Regional School Improvement Service for North Wales (GwE). Recently, the study findings were presented at a Welsh Government seminar on learner effectiveness (Talk Pedagogy). In 2021, we were successful in obtaining funding from the

Welsh Government to conduct a study on the influence of the pandemic on the progress of students (Appendix E). The findings from Welsh Government's Collaborative Evidence Network research project have been written up as a report for the Welsh Government. In 2021, we were also successful in obtaining a research grant from Reaching Wider North and Mid Wales Partnership to evaluate the implementation of the iStER learning resource with schools in disadvantaged regions in North Wales.

Despite Supporting the use of evidence within education, there remains a paucity of accessible guidance surrounding sample size-calculation and survey designs for designing school based-surveys. There are many useful guides and textbooks written on survey research methods for clinical research, and sampling and sample size calculations for survey research which we adapted for our school-based surveys (for sample size calculation see Fox, Hunn & Mathers, 2007; De Vaus, 2014; Fowler, 2014; Pazzaglia, Stafford & Rodriques, 2016). The use of robust survey design is rare within education. Our surveys with students and teachers presented within Chapter 2 and 3 highlighted that much of the earlier survey research in education used non-probability sampling methods. Our survey work highlighted the need to employ more robust survey designs in school settings and more broadly in education research to help us obtain more generalisable findings and thereby, improve the quality of evidence we use for decision-making. The survey design we employed for our surveys with teachers and students presented within Chapters 2 and 3, provided a model for our own survey research which investigated the influence of the pandemic on the independent learning practice of students in Wales (Appendix E). Our survey designs may provide a model for other researchers, teachers, schools interested in conducting robust surveys in educational settings. We suggest that more accessible guidance surrounding survey research methods in education is developed to promote the use of more robust surveys to generate high quality research evidence.

Recommendations of thesis study findings

In this section the recommendation for the thesis studies contained in Chapters 2, 3 and 4 are given.

Recommendations for school leaders and practitioners

Our survey data presented within Chapter 3 suggest that schools and practitioners should define and establish what independent study and revision is. Educators should more clearly communicate the importance of independent learning skills to students, and students would benefit from receiving information about training in using more effective learning strategies such as retrieval and spaced practice for independent study.

Educators should assess students' knowledge of independent learning skills to help them plan improvement actions.

Recommendations for middle Tier organisations (i.e., Local Authorities, ESTYN, School Improvement Consortia) and policy makers

Tier two organisations should evaluate and improve the provision of independent learning strategies in schools. They should ensure initial teacher education programmes emphasise the importance of supporting learners to develop effective independent learning and study skills. Also, providers of initial teacher education programmes should equip early career teachers with the relevant knowledge and understanding about more effective learning strategies.

Tier two organisations should commission ongoing research into both trainee and more experienced teachers recommendations and understanding of evidence-informed learning strategies.

Conclusions

The aim of the current thesis studies was to evaluate the use of evidence-informed learning strategies to help secondary students learn science and improve their independent learning skills. Chapters 2 and 3 describe surveys in Wales schools aimed at assessing the range of learning strategies promoted by school teachers and employed by students, as well as both teachers' and students' understanding of learning strategies. The evidence we gathered from our survey studies in Chapters 2 and 3 informed the next steps in this series of research studies, namely the development of a resource for secondary students to help them use more evidence-informed learning strategies (i.e., a learning resource using retrieval and spaced practice strategies).

Our first survey study conducted in Chapter 3 was the first to employ a robust sampling methodology aimed at gaining a more accurate understanding of students' use of study strategies. It was also the first study to provide a detailed insight into the use of learning strategies by secondary students in the UK. One of the key outcomes from the survey studies presented within Chapters 2 and 3 is that teachers promote a combination of high and low utility strategies and students are not making use of the most effective learning strategies for independent learning. Our survey findings from Chapters 2 and 3 further indicate that a barrier to teachers' recommendations and students' uptake of effective learning strategies is due to a lack of understanding about the effectiveness of learning strategies. Importantly, our findings from all the empirical studies showed there is demand for more information and guidance about effective learning strategies (Chapters 2, 3 and 4).

To help students use more effective learning strategies and improve their independent learning skills we developed the iStER learning resource, and tested the feasibility of lunchtime study/revision to learn GCSE chemistry using the programme. This was a small-scale feasibility trial involving secondary school students. The trial findings were encouraging, and the feasibility results from this small-scale efficacy study support the possibility of a larger evaluation trial. However, in a future, definitive RCT of the iStER intervention, the feasibility of individual randomisation is important to consider.

An unexpected outcome derived from our survey work in Chapters 2 and 3 was that there was a distinct lack of research using robust survey methods in education. We recommend that future surveys in school settings whether these are research driven or teacher based enquiry research should adopt more robust survey designs. Our surveys presented within Chapter 3 may provide a model for future survey work in school settings. We suggest more accessible guidance surrounding sample size-calculation and survey designs is developed by researchers for designing school based-surveys.

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Appendices

Appendix A: Effective Revision and Study Strategies Questionnaire (ERaSSQ) (Chapters 1 and 3)

1. How often do you use the following learning strategies when you study/revise for science? Please tick the box that best describes your answer. The learning strategies are in no particular order.

	Never	Rarely	Sometimes	Most of the time	Always
Using mind maps	☐	☐	☐	☐	☐
Highlighting or underlining information/text	☐	☐	☐	☐	☐
Using flashcards	☐	☐	☐	☐	☐
Reading information/notes over and over	☐	☐	☐	☐	☐
Making notes (summarising)	☐	☐	☐	☐	☐
Spaced practice (spreading study/revision sessions over time)	☐	☐	☐	☐	☐
Doing practice tests (e.g. past papers)	☐	☐	☐	☐	☐
Interleaved practice (mixing different science subjects or science topics while studying/revising)	☐	☐	☐	☐	☐
Elaborate encoding (connecting what you are trying to learn to what you already know e.g. remembering the colours on the visible spectrum by learning the following sentence; Richard Of York Gave Battle in Vain [Red, Orange, Yellow, Green, Blue, Indigo, Violet])	☐	☐	☐	☐	☐

2. If you use a different learning strategy(ies) to study/revise for science, that is not mentioned above, please write this strategy(ies) in the space below.

List of learning strategies (please use this for question 3 below)

- Using mind maps
- Highlighting or underlining information/text
- Using flashcards
- Reading information/notes over and over
- Making notes (summarising)
- Spaced practice (spreading study/revision sessions over time)
- Doing practice tests (e.g. past papers)
- Interleaved practice (mixing different science subjects or science topics while studying/revising)
- Elaborate encoding (connecting what you are trying to learn to what you already know e.g. remembering the colours on the visible spectrum by learning the following sentence; Richard Of York Gave Battle in Vain [Red, Orange, Yellow, Green, Blue, Indigo, Violet])

3. There are two parts to this question. For the first part, using the list of learning strategies above, please write down on the dotted line below, the **THREE** learning strategies that **YOU** most frequently use when you study/revise for science. For the second part, please tick the boxes to show how well **YOU** think the **THREE** strategies that **YOU** have written down help you learn when you study/revise for science.

	Not at all helpful	Slightly helpful	Moderately helpful	Very helpful	Extremely helpful
1)..	☐	☐	☐	☐	☐
2)..	☐	☐	☐	☐	☐
3)..	☐	☐	☐	☐	☐

4. Have any of your current science teachers encouraged you to use any of the following learning strategies when you study/revise for science? Please tick the box.

	Yes	No
Using mind maps	☐	☐
Highlighting or underlining information/text	☐	☐
Using flashcards	☐	☐
Reading information/notes over and over	☐	☐
Making notes (summarising)	☐	☐
Spaced practice (spreading study/revision sessions over time)	☐	☐
Doing practice tests (e.g. past papers)	☐	☐
Interleaved practice (mixing different science subjects or science topics while studying/revising)	☐	☐
Elaborate encoding (connecting what you are trying to learn to what you already know e.g. remembering the colours on the visible spectrum by learning the following sentence; Richard Of York Gave Battle in Vain [Red, Orange, Yellow, Green, Blue, Indigo, Violet])	☐	☐

5. If your science teachers have encouraged you to use a different learning strategy(ies) to study/revise for science that is not mentioned above, please write this strategy(ies) in the space below.

6. Which of the following learning strategies do you use to study/revise for the three science subjects listed below. Please tick the boxes that apply.

	Biology	Chemistry	Physics
Using mind maps	☐	☐	☐
Highlighting or underlining information/text	☐	☐	☐
Using flashcards	☐	☐	☐
Reading information/notes over and over	☐	☐	☐
Making notes (summarising)	☐	☐	☐
Spaced practice (spreading study/revision sessions over time)	☐	☐	☐
Doing practice tests (e.g. past papers)	☐	☐	☐
Interleaved practice (mixing different science subjects or science topics while studying/revising)	☐	☐	☐
Elaborate encoding (connecting what you are trying to learn to what you already know e.g. remembering the colours on the visible spectrum by learning the following sentence; Richard Of York Gave Battle in Vain [Red, Orange, Yellow, Green, Blue, Indigo, Violet])	☐	☐	☐

7. In a typical week how many minutes/hours of study do you do for science outside of lessons? Please tick the box.

- ☐ Less than 1 hours study a week
- ☐ 1 - 2 hours study a week
- ☐ 2- 3 hours study a week
- ☐ 3 - 4 hours study a week
- ☐ 4 - 5 hours study a week
- ☐ 5 - 6 hours study a week
- ☐ 6 - 7 hours study a week
- ☐ More than 7 hours study a week

8. In the weeks leading up to a science test how many minutes/hours do you revise in preparation outside of lessons? Please tick the box.

☐ Less than 1 hour's revision a week
☐ 1 - 2 hours revision a week
☐ 2 - 3 hours revision a week
☐ 3 - 4 hours revision a week
☐ 4 - 5 hours revision a week
☐ 5 - 6 hours revision a week
☐ 6 - 7 hours revision a week
☐ More than 7 hours revision a week

9. Imagine that you are planning to study/revise for an upcoming science test. Please tick the option that best describes your answer, for why you might **do practice tests** (e.g. past papers) to study/revise in preparation for the test. Please only tick **ONE** answer.

☐ Doing practice tests when I study/revise will help me to know how well I have learnt the information for the science test.
☐ Doing practice tests when I study/revise will help me to learn and remember the information for the science test.
☐ I do not think doing practice tests when I study/revise will help me learn and remember the information for the science test.

10. Imagine that you are planning to study/revise for an upcoming science test. Please tick the option that best describes your answer, for why you might **space** (spread) **out** your study/revision sessions in preparation for the test. Please only tick **ONE** answer.

☐ Spacing out my study/revision sessions over multiple days/weeks will help me to learn more information for the science test.
☐ Spacing out my study/revision sessions over multiple days/weeks will help me to learn and remember the information for the science test.
☐ I do not think spacing out my study/revision sessions over multiple days/weeks will help me learn and remember the information for the science test.

11. Imagine that you are planning to study/revise for an upcoming science test. Please tick the option that best describes your answer, for why you might **use flashcards** when you study/revise in preparation for the test. Please only tick **ONE** answer.

☐ Using flashcards when I study/revise will help me to learn because it allows me to read the information over and over.

☐ Using flashcards when I study/revise will help me to learn because it allows me to practise bringing the answer to my mind.

☐ Using flashcards when I study/revise will help me to learn because it helps break up the information into smaller amounts to practise.

☐ I do not think using flashcards when I study/revise will help me learn the information for the science test.

12. Imagine that you are planning to study/revise for an upcoming science test. Please tick the option that best describes your answer, for why you might use **mind maps** when you study/revise in preparation for the test. Please only tick **ONE** answer.

☐ Using mind maps when I study/revise will help me to learn because it allows me to read the information over and over.

☐ Using mind maps when I study/revise will help me to learn because it allows me to practise bringing the information to my mind.

☐ Using mind maps when I study/revise will help me to identify the main topic and link this to related topics, with words that make sense to me.

☐ I do not think using mind maps when I study/revise will help me learn the information for the science test.

13. Is there anything else that you would like to mention about the learning strategy(ies) you use to study/revise for science? Please write in the space below.

Page 2: Section 2

14. Please only answer this question if you are a pupil in Year 10. Does your school offer all pupils in Year 10 study/revision skills support to help you study/revise for science? Please tick the box.

- ○ Yes
- ○ No
- ○ I don't know

15. Do you think that you should be provided with information about effective learning strategies to help you study/revise for science? Please tick the box.

- ☐ Yes
- ☐ No

16. Would you be interested in receiving information about evidence-based learning strategies that will help you to study/revise effectively for science? Please tick the box.

- ☐ Yes
- ☐ No

Page 3: Section 3: Demographics

17. Which school do you go to? Please write down the name of the school in the space below.

18. What is your gender? Please tick the box.

- ☐ Male
- ☐ Female
- ☐ Other
- ☐ Prefer not to say

Appendix B. Sample Size Calculation for Regional Survey with Students (Chapter 1)

To calculate the sample size for our survey with secondary students we used the following formula from the Sampling and Sample Size Calculation guide produced by the National Institute for Health Research Research Design Service (Fox, Hunn & Mathers, 2007).

$$n \geq \frac{\mathrm{z}^2 \times \mathrm{P}}{\mathrm{e}^2 + \left(\frac{\mathrm{z}^2 \times \mathrm{P}}{N}\right)}$$

The formula is based on four parameters. These are: (1) the level of confidence we require concerning the true value of a proportion (or mean); (2) the degree of precision which we are willing to accept; (3) the estimated percentage; and (4) the target population size.

N is the target population size

z represents the z-score that is the desired confidence level (the degree of precision which we are willing to accept)

e is the margin of error (percentage in decimal form) (the confidence interval we are willing to accept)

P is the estimated percentage in decimal form (the proportion of school students that we expect to find using effective/less effective learning strategies)

We specified the following for our survey with school students. Below we present the sample size formula and specify the values for our survey with school students.

P = 0.25. Previous studies on students learning strategy used and well as our pilot survey used non-probability sampling techniques (i.e., convenience), therefore we could not estimate the likely proportion using those findings. Instead, we followed guidelines and assumed that the proportion is likely to be 50%, as this would allow for the largest possible sample size.

z = 1.96

e = 0.03

N = 6,900 we had:

$$\geq \frac{1.96^2 \times\ 0.25}{0.03^2 + \left(\frac{1.96^2 \times\ 0.25}{6{,}900}\right)} = 924 \text{ (rounded upwards)}$$

Using these values, we calculated a sample size of 924 school students aged between 14 and 15 years.

Additional parameters to consider when calculating the sample size include the likely *response rate* and any *clustering effect*. The sampling plan we designed involved inviting all schools, therefore it was not necessary to calculate a response rate. Moreover, as we invited all fifty-four secondary schools in the North Wales region contrary to selecting a sample of schools, this removed any clustering effects at the school levels. Furthermore, our survey design involved sampling students from different science ability groups/classes, contrary to sampling entire classes of students, which removed any clustering at the student level.

Appendix C. Logistic Regression Analysis Model Output (Chapter 3)

Table C. 1 *Estimated response probability values for participating and non-participating secondary schools*

School	Participation in survey	Value	%
1	Responding	0.72759189	72.7
2	Responding	0.65277217	65.2
3	Responding	0.3642495	36.4
4	Responding	0.7602036	76
5	Responding	0.84309707	84.3
6	Responding	0.42637519	42.6
7	Responding	0.47931596	47.9
8	Responding	0.75307349	75.3
9	Responding	0.5310775	53.1
10	Responding	0.70797791	70.7
11	Responding	0.65135538	65.1

School	Participation in survey	Value	%
12	Responding	0.61724712	61.7
13	Responding	0.70259986	70.2
14	Responding	0.85185089	85.1
15	Responding	0.48992396	48.9
16	Responding	0.56952291	56.9
17	Responding	0.54139134	54.1
18	Responding	0.61857378	61.8
19	Responding	1.105661404	90.4
20	Responding	3.345490287	29.8
21	Responding	3.706861813	26.9
22	Responding	1.448201091	69
23	Responding	1.507444954	66.3
24	Responding	1.318875712	75.8

School	Participation in survey	Value	%
25	Responding	2.276885642	43.9
26	Responding	1.597278799	62.6
27	Responding	1.102764154	90.6
28	Responding	1.626240734	61.4
29	Responding	1.743823777	57.3
30	Non-responding	0.33580105	33.5
31	Non-responding	0.79934106	79.9
32	Non-responding	0.79948971	79.9
33	Non-responding	0.685584411	68.5
34	Non-responding	0.5539197	55.3
35	Non-responding	0.46898431	46.8
36	Non-responding	0.39665792	39.6
37	Non-responding	0.41371147	41.3

School	Participation in survey	Value	%
38	Non-responding	0.59187677	59.1
39	Non-responding	0.37902727	37.9
40	Non-responding	0.47580188	47.5
41	Non-responding	0.19048599	19
42	Non-responding	0.52871052	52.8
43	Non-responding	0.19160134	19.1
44	Non-responding	0.56285587	56.2
45	Non-responding	0.0102443	1.02
46	Non-responding	0.42745028	42.7
47	Non-responding	0.09527013	9.5
48	Non-responding	0.59617691	59.6
49	Non-responding	0.41784843	41.7
50	Non-responding	0.46108937	46.1

School	Participation in survey	Value	%
51	Non-responding	0.63695908	63.6
52	Non-responding	0.05520233	5.5
53	Non-responding	0.10503136	10.5
54	Non-responding	0.78675497	78.6

Appendix D. Frequency Outcomes for Survey Item One (Chapter 3)

Table D. 1 *Weighted percentage scores for student responses to the survey question, "How often do you use the following learning strategies when you study/revise for science?" (Survey Item 1)*

Learning strategy	Never	Rarely	Sometimes	Most of the time	Always
	% [CI]	% [CI]	% [CI]	% [CI]	% [CI]
Using mind maps	12.9 [9.0, 18.1]	23.1 [19.3, 27.4]	39.8 [34.7, 45.2]	18.8 [14.3, 24.3]	5.3 [3.2, 8.7]
Highlighting or underlining information	5.7 [3.7, 8.7]	11.9 [8.7, 15.9]	24.8 [20.7, 29.4]	39.1 [33.3, 45.2]	18.5 [13.8, 24.5]
Using flashcards	21.6 [16.3, 28.0]	26.8 [22.0, 32.2]	24.6 [20.7, 29.0]	15.2 [11.6, 19.7]	11.9 [8.0, 17.3]
Repeatedly reading information	5.1 [3.6, 7.3]	12.0 [8.5, 16.7]	17.1 [13.5, 21.4]	33.9 [28.3, 40.1]	31.8 [26.5, 37.7]
Making notes (summarising)	3.9 [1.9, 7.9]	8.4 [6.1, 11.3]	19.4 [15.4, 24.2]	37.9 [32.2, 43.9]	30.4 [25.4, 35.9]

Learning strategy	Never	Rarely	Sometimes	Most of the time	Always
	% [CI]	% [CI]	% [CI]	% [CI]	% [CI]
Spaced practice	12.1 [8.7, 16.4]	21.1 [17.6, 25.1]	29.7 [25.2, 34.6]	22.4 [18.5, 26.7]	14.8 [11.3, 19.2]
Doing practice tests[a]	7.9 [5.3, 11.7]	20.9 [16.0, 26.8]	31.0 [26.1, 36.4]	22.7 [17.3, 29.0]	17.5 [13.1, 23.0]
Interleaved practice	40.6 [35.9, 45.5]	30.3 [25.7, 35.3]	21.6 [17.1, 27.0]	5.6 [3.6, 8.6]	1.9 [0.9, 3.9]
Elaborate encoding	31.8 [25.9, 38.3]	25.7 [20.4, 31.8]	28.5 [24.0, 33.4]	10.6 [7.1, 15.6]	3.4 [2.0, 5.9]

Note. [a]In the present study, we used term *practice tests* to refer to retrieval practice in the ERaSSQ survey.

Appendix E: Full draft report The Influence of COVID-19 on the Independent Study Habits of Learners (Chapter 3: Study 2)

Please note: We have been authorised by Welsh Government to include the Collaborative Evidence Network research study in the current thesis. Here we present the most up to date version of the report which we have sent to Welsh Government. In line with the guidance provided by Welsh Government, throughout the report we use ‘learner’ rather than ‘student’ or ‘pupil’. In addition, we have edited the formatting in accordance with Welsh Government guidelines, including the font style used as well as the layout of the tables and figures.

The Influence of COVID-19 on the Independent Study Habits of Learners

Executive Summary

The purpose of the current research study was to understand and explore the influence of the pandemic on the independent study practice of learners aged 14–15 and 16–17 years in middle and secondary schools in Wales.

We explored learners’ use and understanding of a variety of learning strategies and study resources, as well as how learners felt about undertaking independent study activities and using digital learning platforms. In addition, we explored the sources of learners' knowledge of learning strategies and study resources and how schools supported learners with independent study.

We conducted a cross-sectional survey with learners in mainstream middle and secondary schools in Wales. To measure learners' independent study practice, we asked learners to complete the Effective Revision and Study Strategies Questionnaire (ERaSSQ). Our survey of learners provides the following insight about learners' study practice during the COVID-19 pandemic and at the present time.

Summary of survey findings

Learners’ use of learning strategies and study resources:

1. The study resources that were used most frequently were information/notes in learners’ class book/folder and information notes uploaded by teacher(s) on the school's digital learning platform.
2. The online study resources that were used most frequently were the WJEC website, BBC Bitesize and the Welsh Government’s Hwb platform.
3. The majority of learners used lower utility strategies when using the WJEC website, BBC Bitesize and the Welsh Government’s Hwb platform for study, including highlighting and/or underlining information/text, reading information/notes over and over and making notes and/or summarising information.
4. A minority of learners used the learning strategies categorised as having higher utility, such as retrieval and spaced practice techniques, when accessing the WJEC website, BBC Bitesize and the Welsh Government’s Hwb platform for study.
5. Overall, learners reported using both less and more effective learning strategies whilst accessing the frequently used study resources for independent work. Learners’ choice of strategies has not changed over recent

years and, importantly, despite the need for learners to work more independently during the COVID-19 school closures, learners' use of learning strategies has not changed since the start of the pandemic.

Learners' understanding of the effectiveness of learning strategies and study resources:

1. The learning strategy that scored most highly as being effective was making notes and/or summarising information. This strategy was categorised as a lower utility strategy by Dunlosky et al. (2013).
2. Retrieval practice, categorised as having higher utility by Dunlosky et al. (2013) for enhancing learning, was also rated highly. However, when interpreting these promising results, it is important to consider that around half (49.3%) of learners reported that they would complete retrieval practice activities to assess their learning and fewer than a third (29.7%) would use retrieval practice as a learning strategy.
3. Our survey findings indicate that despite the need for learners to work more independently during the COVID-19 school closures, learners' understanding of the effectiveness of some common learning strategies has not changed since the start of the COVID-19 pandemic.
4. The study resource that was rated most highly as being effective was information/notes in their class book/folder.
5. Two additional study resources were also rated highly as being effective, including using text book/guide and information uploaded by teacher(s) on school learning platforms.
6. Online study resources such as Seneca learning and Oak National Academy were rated as being less effective. (Seneca learning is an online learning resource developed by researchers and is based on retrieval practice, a more effective learning strategy.)
7. The findings indicate that learners were not fully aware of the utility of study resources such as Seneca learning. One reason could be learners' lack of experience using external study resources prior to the COVID-19 school closures, and these findings indicate learners would benefit from receiving more information about the utility of study resources to help them learn.

Learners' knowledge of the benefits of using retrieval practice, spaced practice, flashcards and mind maps as learning strategies:

1. Around half (49.3%) of the learners reported that retrieval practice would help them to assess their learning by identifying what they know and do not know. A minority (29.7%) of the learners reported that they would use retrieval practice as an effective learning strategy. This finding suggests that most learners were not aware of the advantage of using retrieval practice as a learning strategy when studying/revising.
2. Half (53.3%) of the learners reported that spacing practice would have helped them to learn and remember information when studying/revising, suggesting that learners understand that spacing is beneficial for learning.
3. Half (51.3%) of the learners identified the long-term benefits of distributing study sessions over time and only a few (16.2%) believed that studying in only one session was a superior strategy. Our survey findings on spaced practice

suggest that most learners were aware that spacing is beneficial for learning. However, when interpreting these promising results, it is important to consider that we have previously found that only a minority of learners were using spaced practice whilst accessing the various study resources.

4. Around a third of learners (35.8%) reported that using flashcards would help them recall information, suggesting that learners were using flashcards in an effective manner. However, 27.8% of learners reported that using flashcards would allow them to read information over and over (a less effective learning approach). This suggests that some learners might not understand the utility of using flashcards as an effective study tool.
5. Less than a third (31.0%) of the learners reported that using mind maps would help them link information between topics and help them make sense of connections. A similar proportion of learners (29.8%) reported that using mind maps would allow them to reread information over and over, which is a less effective strategy.
6. Despite the lockdown and the need for learners to complete schoolwork on their own, learners' independent study practice and knowledge of the utility of learning strategies has not changed.

Time spent on independent work:

1. Around half (41.4%) of the learners spent more than seven hours a week on schoolwork.
2. The number of hours learners reported spending on independent study per week during the school closures varied between none (11.1%) and more than 7 hours per week (11.7%).

Confidence in using digital learning platforms and confidence towards independent study activities:

1. Our findings show that learners' confidence with using digital learning platforms such as *Hwb Platform, Microsoft Teams, Google Classroom, Moodle* and *Show My Homework* has improved over the period following the first COVID-19 school closures (March 2020 to May 2022).
2. Learners' confidence in using the six digital learning platforms have improved since March 2020 at different rates for the various platforms.
3. The digital learning platform where learners had gained more confidence to use over the lockdown was *Microsoft Teams*.

Learners' confidence in undertaking independent study activities:

1. Learners rated feeling *slightly confident* in undertaking most of the study activities at the start of the COVID-19 school closures. This included undertaking the following activities: *learning schoolwork on my own outside of school without help from school teacher(s); using online learning resources; using the internet for finding effective (i.e., helpful) learning resources; using effective (i.e., evidence-informed) learning strategies; using the internet for finding effective (i.e., helpful) learning strategies; using offline learning resources (e.g., textbooks, study/revision guides); studying on my own*

outside of school (i.e., doing work other than homework); revising on my own in preparation for class tests; and, practising external exams at home.

2. The study activity learners scored most highly as feeling confident in undertaking at the start of the school closures was *using the internet for finding effective (i.e., helpful) learning resources* and learners rated feeling *somewhat confident* in undertaking this activity.
3. An important study activity where learners had gained more confidence to use over the lockdown was *learning schoolwork on my own outside of school without help from school teachers (s)*.
4. Overall, there was a clear improvement on learners' confidence in undertaking the listed study activities with respondents giving a higher rating to all the study activities at the present time of completing the survey compared to at the start of the COVID-19 school closures.

Source of knowledge on learning strategies and study resources:

1. Many (83%) of the learners identified their school teacher as the source of knowledge on learning strategies. Similarly, many (82%) learners identified their school teacher as the source of knowledge on study resources.
2. Half (58%) reported that their knowledge of learning strategies were derived ‘online’ and half (53%) identified their friend(s) and/or peers as the source of their knowledge on learning strategies.
3. Similarly, half (59%) reported that their knowledge of study resources was derived online and half (56%) identified their friend(s) and/or peers as the source of their knowledge on study resources.
4. A minority (40%) reported that their knowledge of learning strategies were derived from parents/carers.
5. Similarly, a minority (35%) reported that their knowledge of study resources were derived from parents/carers.

Support from schools with home learning and demand among learners:

1. Learners rated the support received from schools to help them with their home learning as being moderately helpful, for example using the school’s digital learning platform as well as using other online platforms such as Google Classroom, Microsoft teams to access schoolwork and/or to communicate with your school teacher(s).
2. Our findings also show that many (71.1%) learners would welcome more information about effective learning strategies and study resources.
3. In addition, many (82.5%) learners reported that they should be provided with information about effective learning strategies and study resources to support their independent learning in the event of future emergencies.

Recommendations for Welsh Government

Welsh Government should communicate the importance of independent learning skills, and provide guidance to improve teachers’ knowledge of higher utility independent learning skills that learners can use in secondary and further education settings.

Welsh Government should ensure that an appropriate repository of study skill resources is made available for schools and colleges to help learners use more effective study and revision strategies across a range of subject areas.

Welsh Government should also work with the regional consortia and Estyn to ensure that schools receive appropriate guidance and best practice case studies to help embed the use of effective learning strategies in education settings.

Recommendations for middle tier organisations (i.e., Local Authorities, ESTYN, School Improvement Agencies, Qualifications Wales)

Middle tier organisations should work with Welsh Government and schools to communicate the importance of independent learning skills by providing guidance to improve teachers' knowledge of higher utility independent learning skills to help learners in secondary and further education settings.

Middle tier organisations should monitor the implementation of independent learning intervention programmes in school and college settings. Ensure initial teacher education programmes, and support for newly qualified teachers, includes provision for understanding the importance of supporting learners to use effective independent learning skills.

Recommendations for school leaders and practitioners

Schools should work with teaching staff to more clearly exemplify effective independent study and revision strategies. Schools should also provide learners with information about how to use some of the more effective learning strategies such as retrieval and spaced practice and communicate the importance of how these strategies can be used as part of purposeful independent learning and revision.

Recommendations for future research

Our study did not evaluate parents' and carers' understanding of independent learning skills. Future research should be conducted with parents and carers to explore how they can promote the use of effective learning strategies at home.

Introduction

As part of the Welsh Government National Strategy for Educational Research and Enquiry (NSERE), the Collaborative Evidence Network (CEN) programme of research was established in 2020 to share evidence on the impact of the COVID-19 pandemic on the Welsh education system. In June 2020, Welsh Government commissioned higher education institutions in Wales to undertake the first CEN research studies to understand and explore the influence of the pandemic on the education system in Wales.

In November 2021, Welsh Government commissioned universities in Wales to undertake additional CEN studies. The Collaborative Institute for Education Research, Evidence and Impact (CIEREI), School of Educational Sciences, Bangor University, was awarded a total of twelve projects to investigate the impact of the COVID-19 pandemic across the school system and on important learner groups. The Bangor University CEN programme of research focused on learners, support staff, school leaders, parents/families/carers, and academic staff across the education system in Wales.

The purpose of the current study was to understand and explore the influence of the pandemic on the independent study practice of learners aged 14–15 and 16–17 years in middle and secondary schools in Wales. We asked learners about their experiences of using a variety of learning strategies and study resources for independent learning (i.e., to complete schoolwork, study and/or revision) whilst at home, the time spent on schoolwork and study, and how they felt about independent learning activities and using digital learning platforms. Importantly, we also evaluated learners' understanding of learning strategies and study resources, their source of knowledge of learning strategies and study resources and how schools supported learners with independent study/remote learning. The aim of this research was to gather evidence to inform Welsh Government's Renew and Reform plan and other post-pandemic education policy.

COVID-19 pandemic

During the pandemic, schools in Wales were required to close for two periods between March and June 2020 and December 2020 and April 2021. Apart from vulnerable learners and the children of key workers, all other learners remained at home and were taught remotely (Welsh Government Policy and Strategy, 2021). The COVID-19 pandemic presented unparalleled challenges for schools and learners. In a recent comprehensive review of the literature on young learners during the pandemic in England (Howard, Khan & Lockyer, 2021), the authors concluded that: '...the quantity and quality of teaching and learning declined during the pandemic, most learners appear to have experienced learning losses, with deprived learners and schools serving more deprived regions having suffered disproportionately.'

In Wales, research on the impact of the COVID-19 pandemic showed there were both challenges and opportunities experienced by learners and their families during the school closures. A key challenge for most learners was learning in the home environment. Examples of common barriers for home learning included disruptions in the home environment such as noise, lack of quiet study space, access to remote learning resources including appropriate hardware, internet connectivity, and inadequate parental/carer support with schoolwork (Waters-Davies et al., 2021; Department for Education, 2022). There were variations in the degree of challenges experienced by learners. Some learners with higher levels of parental guidance and support, including greater confidence in undertaking independent learning, made greater gains and were able to progress more easily despite the COVID-19 circumstances.

In Wales, there has been some research surrounding the influence of the pandemic on the independent study practice of learners in secondary and further education settings such as sixth forms and colleges (Mylona & Heledd, 2021; WISERD, 2020). A survey by Mylona & Heledd (2021) on the effects of the pandemic with learners aged 16 or older showed that learners reported both positive and negative experiences of their home learning and their experiences of using online study resources. A similar survey with secondary school learners found most learners reported spending between 6 to 10 hours a week completing schoolwork at home (WISERD, 2020). The most common study resource learners reported using was the BBC Bitesize website. In contrast the Welsh Government's Hwb platform and the Oak National Academy (developed by teachers in response to the pandemic) were the least used online learning platforms as reported by learners. None of these previous studies investigated *how* learners used online study resources to support their learning. There is no published research describing what learning strategies learners might have used whilst studying independently during the pandemic, nor is there any research assessing secondary school learners' confidence in using digital learning platforms. The current study aims to close this knowledge gap.

Given the complexity and uniqueness of learning experiences and learning losses during the COVID-19 pandemic, policy responses to help learners 'catch-up' require a variety of evidence-informed strategies and approaches. This has important implications for Welsh Government's Renew and Reform plan, including learning recovery programmes within schools and colleges. The use of effective learning strategies for independent learning including independent study and revision plays an important role in helping learners in secondary schools 'catch-up' and prepare for external examinations.

Research aims

The aim of the current study is to explore the influence of the pandemic on the independent study practice of school learners aged 14–15 and 16–17 years in Wales. This information will help us to understand whether there is a need for schools to develop further guidance to improve learners' independent study skills to help them 'catch-up' and/or to enable them to make more effective use of their independent study and revision time in preparation for examinations.

Research questions

The research questions are arranged on the key aspects identified on learners' independent study practice, including use and understanding of learning strategies and study resources, time spent on schoolwork and independent study, confidence towards independent study activities and use of digital learning platforms as well as how schools support learners with independent work. The research questions for this study were as follows:

Which study resources did learners use for independent work during the COVID-19 school closures and afterwards?

Which learning strategies did learners use whilst accessing various study resources to support their independent work?

What influence did the pandemic have on learners' understanding of the effectiveness of learning strategies and study resources?

What influence did the pandemic have on learners' knowledge of the benefits of some commonly used and more versatile learning strategies?

How much time did learners invest towards schoolwork and independent study?

What influence did the COVID-19 pandemic have on learners' confidence in using digital learning platforms?

What influence did the COVID-19 pandemic have on learners' confidence towards independent learning?

Where does learners' knowledge of learning strategies come from?

How helpful was the support from schools with home learning?

Is there a demand for information about evidence-informed learning strategies and/or study resources?

Structure of this report

In Section 2 we provide contextual information on the focus of the current report, a review of the existing literature on the independent study habits of school learners' pre-pandemic and during the pandemic.

In Section 3 we describe the research methodology used in this study, including the sampling strategy we used, and the ERaSSQ survey questionnaire completed by learners, to measure learners' independent study practice.

In Section 4 we present the findings of our survey with learners to provide an insight into learners' study practices during the pandemic and at the present time.

In Section 5 we present a discussion of our survey findings with learners and provide recommendations for policy makers.

In this report we use the term independent study practice and independent work interchangeably to refer to schoolwork, study and revision learners completed on their own during the COVID-19 pandemic school closures and afterwards. The overarching terms include school work, independent study and revision, except when the focus is on one of these aspects and not all then we use that term.

Literature Review

Acquiring independent learning skills is an important developmental milestone that enables students to be more independent lifelong learners. A recommendation proposed from the findings of the research studies on the impact of the COVID-19 pandemic on the Welsh Education System for 2020 was that the new curriculum should consider the importance of independent learning (Welsh Government The National Strategy for Education Research and Enquiry, July 2021). An important aspect of independent practice includes the learning strategies learners use during independent study. Research suggests the learning strategies learners use during independent study are related to the outcomes they achieve (Bartozewski & Gurung, 2015; Gurung, Weidert & Jeske, 2010; Hartwig & Dunlosky, 2011; Rodriquez, Rivas, Matsumura, Warschauer & Sato, 2018). Learning strategies are the activities learners undertake for their independent work, in other words, *how* they go about learning key content and ideas on their own outside of the classroom (Oakes & Griffin, 2016).

Research suggests that two strategies, retrieval practice and spaced practice, are more effective in helping learners achieve educational outcomes (Agarwal, Nunes & Blunt, 2021; Dunlosky et al., 2013; Karpicke & Roediger, 2006). Dunlosky et al. (2013) evaluated retrieval practice and spaced practice alongside eight other commonly used learning strategies (and arranged these into low, medium and higher utility categories) according to their effectiveness for enhancing learning based on how effectively the strategies can be used across a range of learning tasks and situations. Of the ten learning strategies, two strategies were identified as high utility (retrieval practice and distributed practice [note that we use the term spaced practice here]), three strategies were identified as having moderate utility (interleaved practice, elaborative interrogation and self-explanation), and five strategies were identified as having low utility (summarising, highlighting [or underlining], using keyword mnemonics, imagery use for text learning and repeatedly reading information). These findings have important implications for learning and teaching and for learners' independent study skills.

In this research study we focused on the evaluation of six of the learning strategies described by Dunlosky et al. (2013) as well as five other commonly used learning strategies identified in the literature on learners’ study practice. Table E.1 presents the learning strategies included in this study and a description of the learning strategies.

Table E. 1 *Overview of commonly used learning strategies evaluated in the current study*[a]

Learning strategy	Description
Highlighting or underlining information/text	To mark out important content (i.e., key words, text) of the to be learned material with a bright/different colour while reading
Reading information/notes over and over	Reading information over and over
Making notes and/or summarising information	Writing notes/summaries (of various lengths) of the information to be learned
Spaced practice	Implementing a schedule of study/revision practice where study time is separated into multiple sessions overtime. Reviewing learning materials studied earlier in later sessions
Retrieval practice	Retrieving information from memory in absence of the information to be remembered by using practice tests, past papers, quizzes, flashcards (or any other activity which involves actively retrieving information from memory)
Interleaved practice	Mixing study of different, related topics, concepts or problems. Implementing a schedule of study practice that mixes different kind of skills, subjects or topics within a single study session
Elaborate encoding	Connecting what you are trying to learn to what you already know (e.g., using mnemonics). Making connections between information to be learned and other information.
Using mind maps	Writing down a key topic, and from this creating links composed of keywords, phrases, concepts, facts and figures. Mind maps are typically presented as diagrams.
Using flashcards	Writing key terms, facts or to be learned information on small cards. Flashcards are

Learning strategy	Description
	typically two-sided with the prompt / question appearing on one side and the information about the prompt / answer on the other).
Watching videos on the subject topic[b]	Watching videos related to the subject topic on
Listening to audio on the subject topic[c]	Listening to audio related to the subject topic

Note. [a]This study assessed the use of six learning strategies evaluated by Dunlosky et al. (2013). In the current study, five additional learning strategies identified in the literature on learners' study habits were also included (elaborate encoding, using mind maps, using flashcards, watching video on the subject topic, listening to audio on the subject topic). [b],[c]These two strategies were identified from our earlier survey with school learners use of independent study practice (Sultana et al., 2023).

Effective learning strategies

Retrieval practice is a learning strategy based on retrieving information from memory (i.e., practising recall) in absence of the information to be learnt. The process of retrieval strengthens the memory for that information, leading to enhanced long-term learning and improved recall of information (Bjork & Bjork, 2011; Roediger & Karpicke, 2006). Retrieval practice is also referred to as the 'testing effect'. This describes the finding that being tested on information can result in better recall of the information (Roediger & Karpicke, 2006). Examples of retrieval practice activities include completing quizzes, class tests, past paper exam questions, using flashcards, writing notes from memory. The key feature in all retrieval activities is that information is actively recalled from memory and not passively re-read.

Survey studies with university and secondary learners have shown that learners were using retrieval practice activities for independent study. However, learners were using this strategy less frequently compared to suboptimal strategies and not in a way that facilitates learning (Agarwal et al., 2014; Bartozewski & Gurung, 2015; Biwer, Egbrink, Aalten & de Bruin, 2020; Blasiman, Dunlosky & Rawson, 2017; Dirkx et al., 2019; Gurung et al., 2010; Hartwig & Dunlosky, 2011; Karpicke et al., 2009; Kornell & Bjork, 2007; McAndrew, Kamboj & Pierre, 2015; McAndrew, Morrow, Atiyeh & Pierre, 2016; Peña, Knecht & Gavaza, 2021; Piza, 2018; Rodriguez et al., 2018; Susser & McCabe, 2013; Morehead, Rhodes & DeLozier, 2016)**.** Survey results revealed that learners primarily use retrieval practice as a diagnostic tool to evaluate their learning, rather than as a method to actually *learn* information (Hartwig & Dunlosky, 2012; Kornell & Bjork, 2007; Kornell & Son, 2009; McAndrew et al., 2016; McCabe, 2011; Morehead et al., 2016; Piza, 2018; Schmidmaier et al., 2011).

One of the reasons that learners use retrieval practice as a diagnostic tool might be because many will be familiar with their experience of completing quizzes, class tests, to find out how well they have learnt information and teachers using class tests, past paper questions to find out how well the information has been learnt.

This study aims to assess how learners might have used retrieval practice to complete independent work during the school closures, and to update our knowledge on how learners identify this effective learning strategy. Information on learners' use and understanding of effective learning strategies for study can provide insight and understanding on how learners use effective learning strategies. In addition, this can provide valuable evidence to inform Welsh Government advice to schools on the most effective strategies to help learners catch up. Retrieval practice can also be used as an effective formative assessment method to help assess learners independent learning to help improve their study skills.

Spaced practice is a learning strategy which involves implementing a schedule of study/revision practice where study time is separated into multiple sessions overtime and reviewing previously learnt information in successive sessions. This can help to slow down the rate of forgetting newly learned information leading to enhanced learning. This learning strategy is underpinned by the forgetting curve (Ebbinghaus, 1885/2006), and has been shown to be effective by subsequent research (Bahrick et al., 1993; Kornell, 2009; Sobel, Cepeda & Kapler, 2011; Kim, Wong-Kee-You, Wiseheart, & Rosenbaum, 2019). Studies with university and secondary school learners have shown that although learners are aware of the spacing advantage, they reported using spaced practice less frequently compared to more suboptimal learning strategies such as repeated reading (Dirkx et al., 2019; Susser & McCabe, 2013; Sultana et al., 2023). The inconsistency between learners' knowledge and utilisation of spaced learning may be partly to do with the lack of knowledge about the learning advantage of spaced practice. Another explanation for this is that it is a strategy that advises on *when* rather than *how* to practise and is therefore less likely to be viewed as a practical learning strategy in its own right. The current study aims to assess learners' use of spaced practice for independent learning during the school closures as well as learners' awareness of the spacing advantage.

Use and understanding of learning strategies

Previous research on learners' study practice in university and secondary school settings has shown that learners predominantly use less optimal learning strategies such as repeated reading approaches, highlighting [or underlining] information and summarising information, compared to more effective learning strategies such as retrieval and spaced practice and have inaccurate and/or incomplete understanding about the effectiveness of the learning strategies they use (Agarwal et al., 2014; Bartozewski & Gurung, 2015; Biwer, Egbrink, Aalten & de Bruin, 2020; Blasiman, Dunlosky & Rawson, 2017; Dirkx et al., 2019; Gurung et al., 2010; Hartwig & Dunlosky, 2011; Karpicke et al., 2009; Kornell & Bjork, 2007; McAndrew, Kamboj & Pierre, 2015; McAndrew, Morrow, Atiyeh & Pierre, 2016; Peña, Knecht & Gavaza, 2021; Piza, 2018; Rodriguez et al., 2018; Schmidmaier et al., 2011; Susser & McCabe, 2013; Morehead, Rhodes & DeLozier, 2016). The current authors conducted a similar survey study with learners aged 14–15 years in secondary schools in North Wales and found similar results (Sultana et al., 2023). The findings are in line with those of previous studies mentioned above. The findings reflect what is found in the earlier studies mentioned above on learners' study habits which showed that learners rarely make use of effective learning strategies.

Learners typically use learning strategies to study and/or revise in preparation for assessments and exams. During the school closures caused by the COVID-19 pandemic most learners were completing schoolwork on their own whilst at home. Given the change in the delivery of schoolwork as well as the increased autonomy on learners to undertake independent work during the pandemic, it is important to investigate any change in learners' independent study habits. Existing studies into the impact of the pandemic with learners in secondary and further education settings explored the learning experiences of home learning and using study resources and there remains an absence of research on learners' use and understanding of learning strategies (WISERD, 2020; Mylona & Heledd, 2021). There is no published research describing what learning strategies young learners might have used to study whilst studying at home during the pandemic, nor is there any research evaluating to what extent secondary learners study practice has been influenced by the pandemic. This research aims to close this gap by gathering evidence on how learners use learning strategies and the influence of the COVID-19 pandemic. This will provide valuable evidence for Welsh Government, schools, and school improvement professionals as they design post-pandemic support.

Other key aspects of independent study

There are other key aspects of independent study practice such as investing effort including time for independent study and revision, confidence towards using digital learning platforms and confidence towards independent learning skills, learners source of information on learning strategies (Oakes & Griffin, 2016). Oakes and Griffin (2016) proposed one way to encourage high levels of effort is to communicate how many hours a week learners should consider investing for independent study. A combination of these aspects is important for independent work. In addition to investigating *what* learning strategies and study resources learners use we also examined 'why' learners might rely on lower utility strategies. In the current study we also examined where learners' knowledge about learning strategies and resources came from, the time invested towards independent study and how confident learners felt about independent study and using digital learning platforms. Over the years the notion that learners have different learning styles has become widespread within the education field, however in an important review of the literature on learning styles by Pashler, McDaniel, Rohrer and Bjork (2008) the authors concluded that there was no robust scientific evidence to support the learning style theory. More recent research also showed that there was a lack of evidence to support that learners learn better when instruction is tailored to their learning styles (Nancekivell, Shah & Gelman, 2019). For this reason, in the current study with school learners, we did not investigate different learning styles.

The current study also uses a sampling method that differs significantly from that of earlier studies. There have been no studies of this nature that have used probability sampling methodologies to explore the influence of the pandemic on secondary age learners. The present study used a random sampling method to obtain a representative sample of learners aged 14–15 and 16–17 years in secondary schools in Wales.

Methodology

Research design

In this research study we used a cross-sectional survey. This study was conducted as part of other Bangor University led CEN school research projects where schools in Wales were sampled and invited to participate. Schools for the current study were subselected from a larger sample required for other Bangor University CEN projects. The study population for the current study was school learners in Year group 10 and Year group 12, and in the other CEN projects the study populations included school teachers, parents/carers. There was no interest in Year 10 and Year 12 learners in the other CEN projects, therefore, learners did not receive multiple questionnaires from different projects.

Sample description

The target population for the current study was defined as learners aged between 14 and 15 years (school Year group 10) and 16 and 17 years (school Year group 12) studying GCSE and A Level qualifications in mainstream middle and secondary schools in Wales.

A multistage clustered sample design was used for a sample selection. There were two stages to the sampling procedure. This sampling approach was taken as learners are registered in schools and to obtain a sample of school learners we had to first invite a sample of schools. An advantage of cluster sampling includes lower cost and lower effort for the same effective sample size, that is the same level of confidence intervals, compared with a simple random sample (Kish, 1995). The sample selection followed all the steps for selecting a probability sample in order to represent a population as described by Kish on survey sampling (Kish, 1995).

At the first stage of the sampling process, secondary schools were selected from a list ordered by local authority (Blaenau Gwent, Bridgend, Caerphilly, Cardiff, Carmarthenshire, Ceredigion, Conwy, Denbighshire, Flintshire, Gwynedd, Isle of Anglesey, Merthyr Tydfil, Monmouthshire, Neath Port Talbot, Newport, Pembrokeshire, Powys, Rhondda Cynnon Taf, Swansea, Vale of Glamorgan, Torfaen and Wrexham), and within region by language medium (dual stream, English medium, English with significant Welsh, Transitional and Welsh medium) and the percentage of learners in schools eligible for free school meals (eFSM) (mean percentage scores) for 2019/21. At the second stage, we invited all learners in Year group 10 and Year group 12 in each of the schools that accepted the survey invite, to complete the Effective Revision and Study Strategies Questionnaire

(ERaSSQ). This approach was taken to minimise unnecessary class disruption in schools. A detailed explanation of the ERaSSQ survey is given in sub section 2.4 below titled *survey measure*.

Survey procedure

We obtained ethical approval for the study from the School of Educational Sciences Research Ethics Committee of Bangor University (ethical approval number: 17022022-1628). The invitation to complete the online questionnaire was sent to headteachers in selected schools in the six regional consortia and partnerships in Wales in March 2022 (these are GwE, EAS, Mid Wales Partnership, CSC, Neath Port Talbot, Partneriaeth). Schools were invited to attend information sessions in March and April 2022 to explain the purpose of the surveys in more detail. Finally, a follow-up reminder email was sent to schools in May 2022 by the regional consortia and partnerships and emphasised that the CEN research officers would be contacting schools with a courtesy follow-up reminder phone call. Between May and June 2022, a final follow-up phone call was made to the schools to encourage head teachers to engage with the CEN surveys.

Once a school accepted the CEN project invite, the survey link for the Effective Revision and Study Strategies Questionnaire was sent to the school headteacher and/or nominated member of staff to forward on to all learners in Year group 10 and Year group 12 to complete. The survey was available in both Welsh and English.

Study information was sent to the school headteachers. This informed the school headteacher about their learners' participation in the survey. In the first page of the survey, we provided a written introduction that explained the purpose of the research study and explained how the survey could be completed. We emphasised that learners' answers would be treated confidentially, that there were no 'right' or 'wrong' answers, and that their responses would not reflect on their current performance in school or that of their school. The learners were given the opportunity to consider their participation in the survey, opt-out or provide consent prior to completing the questionnaire. The online questionnaire was completed by learners on their own in school. Completion of the questionnaire required approximately 20 minutes. Learners were thanked for their assistance and given a written debrief about the study. Neither learners nor schools were remunerated for their participation in the survey.

The school invitation letters and reminders were undertaken as part of other Bangor University CEN school projects where the headteachers of the selected schools were invited to other CEN projects. Schools for the current study were subselected from a larger sample required for other Bangor University CEN projects. The study population for the current study was school learners in Year group 10 and Year group 12, and in the other CEN projects the study populations included school teachers, parents/carers. There was no interest in Year 10 and Year 12 learners in the other CEN projects, therefore, learners did not receive multiple questionnaires from different projects. We used the same procedure to contact the schools for all the Bangor University CEN studies and one email invitation letter was sent via the regional consortia and partnerships containing an invitation for schools to the CEN studies, instead of multiple emails being sent on the individual CEN projects. This meant multiple emails were not sent to the headteachers of the selected schools. This approach was taken to minimise the number of invitations school headteachers were sent and thus to help the survey response rate. In total, seven schools accepted the survey invite. This represents a response rate of 21.86% at the school level. Of the participating schools, responses from 74 learners were obtained.

Survey measure

We used the ERaSSQ survey to measure learners' study practice for independent work including, schoolwork, study and/or revision from the start of the COVID-19 pandemic until the study end date (May 2022). The survey was developed using the Online Surveys programme (https://www.onlinesurveys.ac.uk/). The ERaSSQ survey was developed by the current authors to answer research questions as part of a PhD thesis evaluating the use of evidence-informed learning strategies for improving secondary school learners' independent study practice (Sultana, 2023). To inform the development of the survey items, key aspects of learners' independent study practice were identified following a review of the literature (Blasiman et al., 2017; Dunlosky et al., 2013; Kornell and Bjork, 2007; Oakes & Griffin, 2016). These included school learners use and understanding of learning strategies, effort towards independent work, and school-based support with study/revision. There are 18 survey items that use a closed-ended (Likert scale, multiple choice) and open-ended format. The ERaSSQ survey has previously been used for a regional survey with 385 secondary school learners in North Wales (Sultana et al., 2023). The aim of the regional survey was a scoping exercise to explore secondary school learners use and understanding of evidence-informed learning strategies and more broadly their independent study practice. In addition, the evidence we collated have been used to develop a learning programme called the Improving Standards through Effective Revision (iStER) programme, for improving secondary learners independent study practice.[1] The findings from the regional survey has been submitted to the School of Human and Behavioural Sciences, Bangor University in partial fulfilment for the degree of Doctor of Philosophy, and is being prepared to submit for publication in an academic journal.

For the present study, we used a modified version of the ERaSSQ survey with learners in Year group 10 and Year group 12. The ERaSSQ has been modified following peer review in an academic journal and to reflect appropriate changes in learners’ education that relate to the COVID-19 pandemic. The modified version of the ERaSSQ contains new survey items designed to measure secondary school learners use and understanding of learning strategies as well as *study resources*, effort towards *independent schoolwork* and study, *where learners’ knowledge of*

[1] The findings from the ERaSSQ have been used by the Regional School Effectiveness and Improvement Service for North Wales (GwE) to support PhD studentship research to develop a learning programme called the Improving Standards through Effective Revision (iStER) programme. The findings from the regional survey has been submitted to the School of Human and Behavioural Sciences, Bangor University in partial fulfilment for the degree of Doctor of Philosophy, and is being prepared to submit for publication in a journal.

learning strategies and study resources come from, *confidence in using digital learning platforms* and in their *independent study skills* and h*ow schools supported learners with independent work*. Minor modifications were also made to the wording of the survey items such as learning strategy terms, response options as well as the addition of new learning strategies following findings in our previous regional survey with school learners. The changes that were made to the ERaSSQ survey for the current study are presented in Table Q.1 (see Appendix Q).

The survey items in the ERaSSQ relate to the current research questions outlined in the introduction section. The survey items for the modified version of the ERaSSQ in this study were as follows:

Use and understanding of learning strategies and learning resources. The first section of the survey asked learners about the learning strategies and study resources used from the start of the COVID-19 pandemic until May 2022. To measure the use of study resources, we asked learners to rate how often they used the twelve common study resources on a 5-point Likert scale from never (1) to always (5) (see Appendix R). We also gave learners the opportunity to write down any additional study resources. We then asked learners to indicate whether they used any of the common learning strategies whilst accessing any of the twelve study resources listed in the survey question. We also gave learners the opportunity to indicate if they did not use any of the learning strategies whilst accessing any of the study resources.

To measure learners' understanding of the effectiveness of common learning strategies, we asked learners to rate the eleven learning strategies on how effective they believed the strategies to be on a 5-point Likert scale from not at all helpful (1) to extremely helpful (5). We also asked learners to rate how effective they believed the twelve study resources to be on a 5-point Likert scale from not at all helpful (1) to extremely helpful (5). The option of 'I am not sure' was also included in these questions.

To measure knowledge of the benefit of retrieval practice, we asked learners to choose one option out of multiple alternatives that best indicated how they would practise to prepare for a forthcoming examination. Using the same question style, we also measured knowledge of the spacing advantage, using flashcards and using mind maps to study/revise. To measure awareness of the spacing advantage in a different way, we asked learners to choose one response option from a choice of three response options on spacing practice presented to them, the learning strategy which they think research has found to be effective for learning (informed by Susser and McCabe, 2013). If learners indicated that studying the material in multiple sessions of shorter duration is the method that research has found to be effective for long-term retention, then we would infer learners understand there is an advantage to spaced study.

Effort towards schoolwork and independent study (i.e., time spent on schoolwork and independent study). To measure effort towards schoolwork (i.e., time spent on schoolwork), we asked learners how many hours of schoolwork they did whilst at home during the COVID-19 school closure. To measure effort towards independent study (i.e., time spent on independent study), we asked learners how many hours of independent study they did whilst at home during the COVID-19 school closure.

Confidence levels on using digital learning platforms. To measure learners' confidence in using digital learning platforms at the start of the COVID-19 school closures, we asked learners to rate how confident they felt using the common digital learning platforms on a 5-point Likert scale from not confident at all (1) to extremely confident (5). We also asked learners to rate how confident they now felt about using the common digital learning platforms on a 5-point Likert scale from not confident at all (1) to extremely confident (5). Learners could also write down any additional digital learning platform not listed in the survey question and rate how confident their initial and current confidence of using the platform they had noted on a 5-point Likert scale from not confident at all (1) to extremely confident (5). We also gave learners the option of 'Our school/We did not use this' to indicate platforms they had not used.

Confidence levels on independent study skills. To measure learners' confidence in their independent study skills at the start of the COVID-19 school closures, we asked learners to rate how confident they felt about independent study skills and learning activities on a 5-point Likert scale from not confident at all (1) to extremely confident (5). We also asked learners to rate how confident they now felt about the independent study skills and activities on a 5-point Likert scale from not confident at all (1) to extremely confident (5). These study skills and learning activities were: *learning on their own without help from teacher(s)*, *using online learning resources*, *using the internet for finding effective learning resources, using effective learning strategies, using the internet for finding effective learning strategies, using offline learning resources, independent study,* and *independent revision*.

Knowledge of learning strategies and study resources. To measure where learners' knowledge about learning strategies and study resources come from, we asked learners to select all relevant listed sources. There were seven options relating to the source of learning strategies and study resources. These were: *school teacher(s), school study/revision tutor, school study/revision support centre, parents/carers, friend(s)/peers, online, and private tutor(s).*

Getting support from schools. To measure support with home learning relating to the COVID-19 pandemic, including using digital communication and learning platforms, we asked learners to rate how helpful the support they received from schools was on a 5-point scale from not at all helpful (1) to extremely helpful (5).

Statistical analysis

We used post-stratification techniques to adjust for survey non-response by matching the responding dataset to the school population data set for the number of learners in Year 10 and Year 12. Our analysis therefore reflects the number of learners population distribution. In addition, any variables that are related to the number of learners also are corrected for non-response to the extent that they are related to the number of learners, such that the potential non-response bias related to the number of learners is eliminated fully after post-stratification. The population data on total year group numbers were obtained from the sample frame. We obtained the contextual school data for 2021/22 from Welsh Government Statistics for Wales. We could not correct for clustering, due to confidentiality reasons school names were not collected. This was to ensure learners' responses could not be linked back to the schools. Any clustering effect is expected to be low due to the relatively low response rate within schools. Not taking account of clustering in the analysis does not effect the point-estimates, which are still unbiased, however, affects confidence intervals. In such situations the confidence interval is slightly wider than it should be if clustering is accounted for. The effect would be minor considering that due to the low nonresponse the size of the clusters was smaller.

We report the percentage scores for the survey results with learners according to the following categories proposed by Estyn (2022). These are as follows:

Nearly all = with very few exceptions
Most = 90% or more
Many = 70% or more
A majority = over 60%
Half = 50%
Around half = close to 50%
A minority = below 40%
Few = below 20%
Very few = less than 10%

Results

This section presents the results of the ERaSSQ survey with school learners. The findings are presented below according to the research questions outlined in the introduction section.

Which study resources did learners use for independent work during the COVID-19 school closures and afterwards?

We asked learners about the study resources they used for independent work. We asked learners to indicate how often they used the twelve study resources for schoolwork, study and/or revision at home since the start of the COVID-19 pandemic school closures until the present day. Learner ratings of the study resources were made on a 5-point scale from never (1) to always (5). Table E.2 shows the twelve study resources and the weighted percentage of learners reporting the various frequencies per study resource, arranged from most to least often used. The study resources that scored most highly as being used were those provided by schools such as information/notes in their class book/folder and information notes uploaded by teacher(s) on the school's digital learning platform. The online study resources that scored most highly as being used were the WJEC website, BBC Bitesize and the Welsh Government's Hwb Platform (Table E.2).

Table E. *2* *Weighted percentage scores for learner responses to the survey question, "Since the start of the COVID-19 pandemic until the present day, how often did you use the following learning resources to learn schoolwork, study and/or revise at home?"*

Learning resource	**Always**	**Most of the time**	**Sometimes**	**Rarely**	**Never**
	% [CI]	**% [CI]**	**% [CI]**	**% [CI]**	**% [CI]**
Information/notes in class book/folder	34.5 [24.1, 46.6]	35.2 [25.0, 47.1]	16.6 [9.5, 27.5]	7.4 [3.3, 15.9]	6.2 [2.5, 14.3]
Information/notes uploaded by teacher(s) on school's digital learning platform	31.5 [21.6, 43.4]	37.0 [26.4, 49.0]	17.9 [10.5, 28.9]	8.7 [4.1, 17.4]	5.0 [1.8, 12.8]
WJEC website	15.7 [8.5, 27.3]	22.8 [14.2, 34.4]	24.1 [15.4, 35.5]	16.5 [9.4, 27.3]	20.9 [13.0, 2.0]
BBC Bitesize	7.4 [3.3, 15.9]	19.8 [12.0, 30.7]	38.8 [28.0, 50.9]	21.0 [12.8, 32.4]	13.0 [7.0, 22.9]
Hwb Platform	16.5 [9.4, 27.3]	22.8 [14.2, 34.4]	15.2 [8.4, 25.9]	15.8 [8.8, 26.8]	29.8 [20.1, 41.6]
Text book/guide	18.7 [10.7, 30.4]	23.1 [14.6, 34.6]	9.4 [4.4, 18.8]	13.1 [7.1, 23.2]	35.7 [25.3, 47.6]

Learning resource	**Always**	**Most of the time**	**Sometimes**	**Rarely**	**Never**
	% [CI]	**% [CI]**	**% [CI]**	**% [CI]**	**% [CI]**
Quizlet	3.8 [1.2, 11.3]	4.4 [1.3, 13.2]	25.0 [16.3, 36.5]	27.5 [18.2, 39.3]	39.3 [28.4, 51.4]
AQA website	3.1 [0.7, 12.2]	2.5 [0.6, 9.8]	5.6 [2.0, 14.5]	8.1 [3.6, 17.4]	80.6 [69.4, 88.4]
Tanio.Cymru	1.3 [0.2, 8.8]	2.5 [0.6, 9.8]	5.0 [1.8, 12.9]	6.3 [2.6, 14.5]	84.9 [74.9, 91.4]
Khan Academy		1.9 [0.2, 12.5]	6.8 [2.5, 17.2]	5.0 [1.8, 12.9]	86.3 [75.3, 92.9]
Seneca Learning			1.3 [0.2, 8.8]	6.3 [2.6, 14.5]	92.5 [83.9, 96.7]
Oak National Academy			1.3 [0.2, 8.8]	3.8 [1.2, 11.3]	95.0 [87.1, 98.2]

Note. Learning resources are ordered by frequency of use, from most to least often used.

Which learning strategies did learners use whilst accessing various study resources to support their independent work?

Next, we asked learners about which learning strategies they were using to support their learning whilst accessing different study resources for independent work. This included six of the learning strategies categorised by Dunlosky et al. (2013) into three groups based on whether they considered them having high, medium or low utility for their effectiveness in enhancing learning. The effectiveness ratings were assigned depending on the strength of the underlying evidence to support their evidence in research. The learning strategies categorised as ‘high’ utility were spaced practice and retrieval practice, and the learning strategy categorised as ‘moderate’ utility and included in the current study was interleaved practice. The learning strategies categorised as ‘low’ utility were highlighting and/or underlining information, reading information/notes over and over and interleaved practice. Three additional learning strategies identified in the literature were also included (*using flashcards*, *using mind maps* and *elaborate encoding*), although we do not include a utility rating for these three strategies because they were not evaluated by Dunlosky et al. (2013). These three strategies are commonly used strategies by learner populations, for this reason, we also explored *whether* learners were using these strategies.

Figures E.1 to E.9 show the nine common learning strategies and study resources, and the percentage of learners who reported using the strategies whilst accessing the various study resources for independent work. Our survey results above on learners' use of study resources showed that the most frequently used study resources were information/notes in their class book/folder and information notes uploaded by teacher(s) on the school's digital learning platform (Table E.2). Our survey results on which learning strategies learners were using with these most frequently used study resources show that a majority of learners were using the strategies considered to have low support, including highlighting and/or underlining information/text, reading information/notes over and over and making notes and/or summarising information (Figures E.2, E.4 and E.5). In contrast, a minority were using the learning strategies retrieval and spaced practice categorised as having high support whilst accessing these study resources (Figures E.6 and E.7). Overall, survey results showed learners reported using both less and more effective learning strategies for independent work whilst accessing these frequently used learning resources.

Figure E. 1 *Percentage of learner responses to the survey question, “Since the start of the COVID-19 pandemic until the present day, for any of the learning resources listed below have you* ***used and/or made your own mind maps*** *whilst accessing any of these learning resources for schoolwork, study and/revision at home?”*

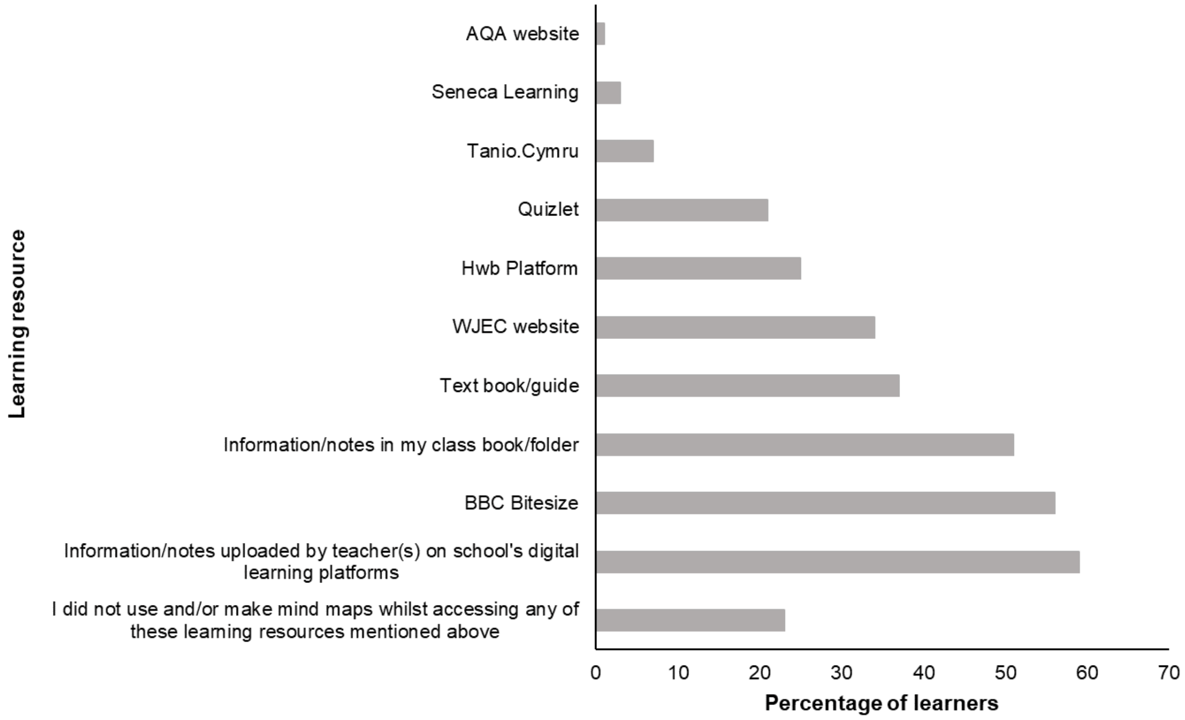


Figure E. 2 *Percentage of learner responses to the survey question, "Since the start of the COVID-19 pandemic until the present day, for any of the learning resources listed below have you* ***highlighted and/or underlined information/text*** *whilst accessing any of these learning resources for schoolwork, study and/or revision at home?"*

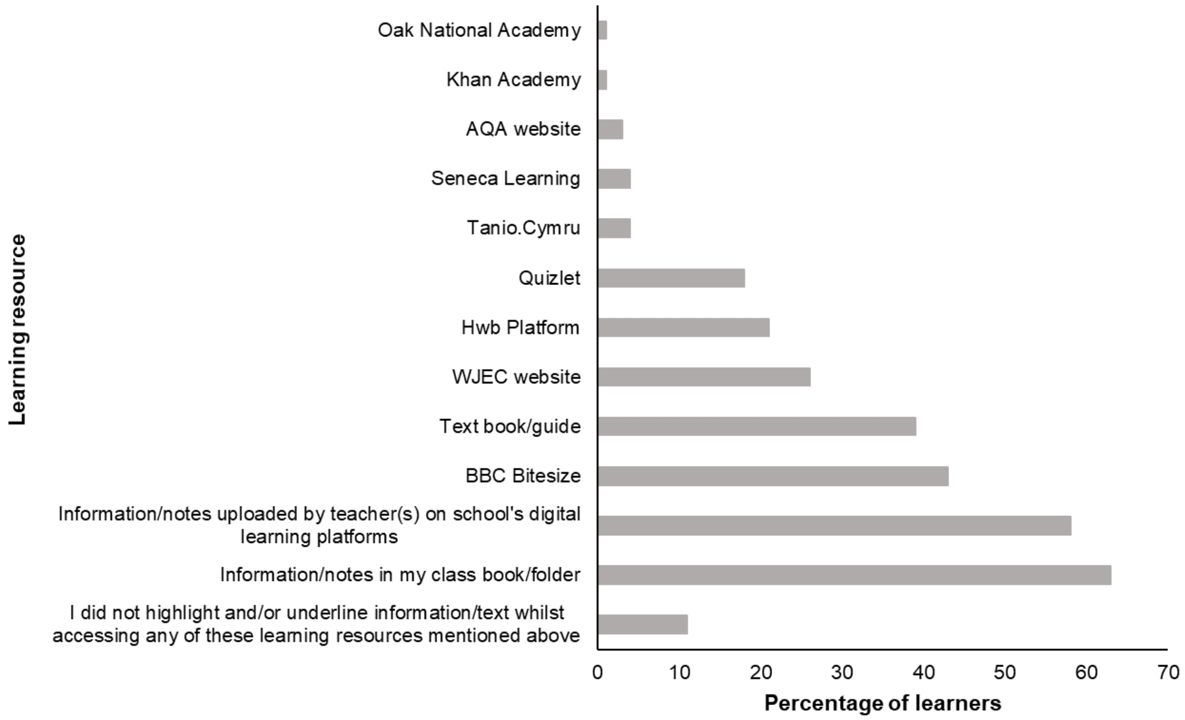


Figure E. 3 *Percentage of learner responses to the survey question, "Since the start of the COVID-19 pandemic until the present day, for any of the learning resources* *listed below have you* ***used and/or made your own flashcards*** *whilst accessing any of these learning resources for schoolwork, study and/or revision at home?"*

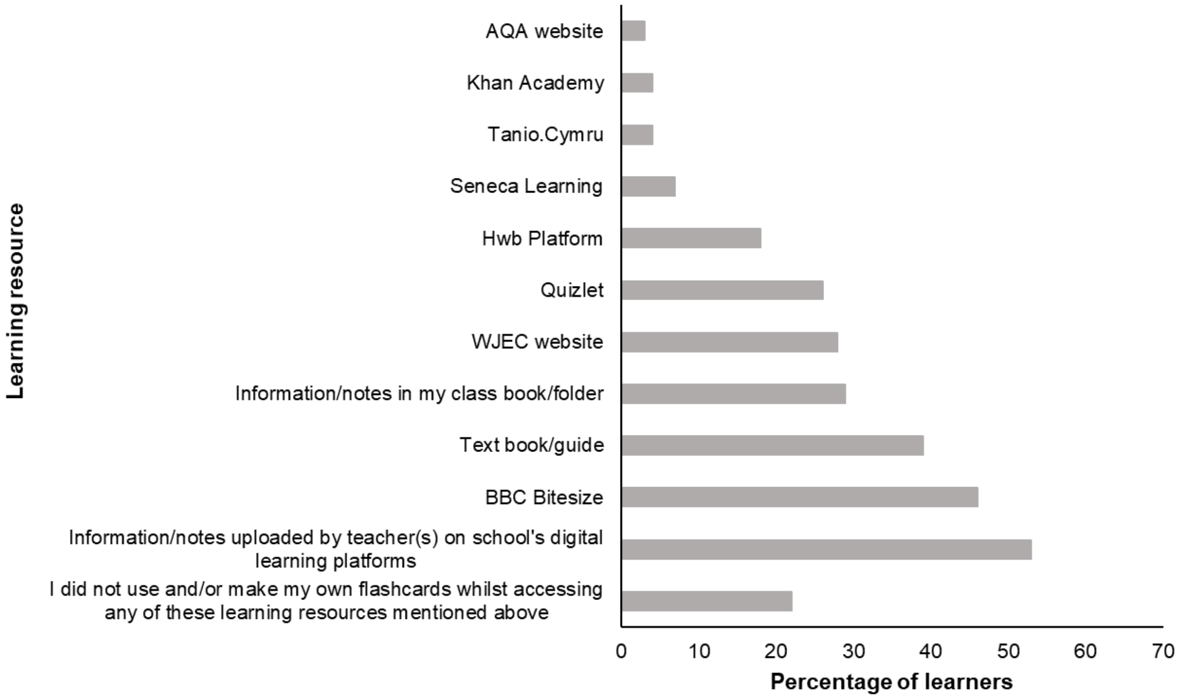


Figure E. 4 *Percentage of learner responses to the survey question, "Since the start of the COVID-19 pandemic until the present day, for any of the learning resources listed below have you* ***read information/notes over and over*** *whilst accessing any of these learning resources for schoolwork, study and/or revision at home?"*

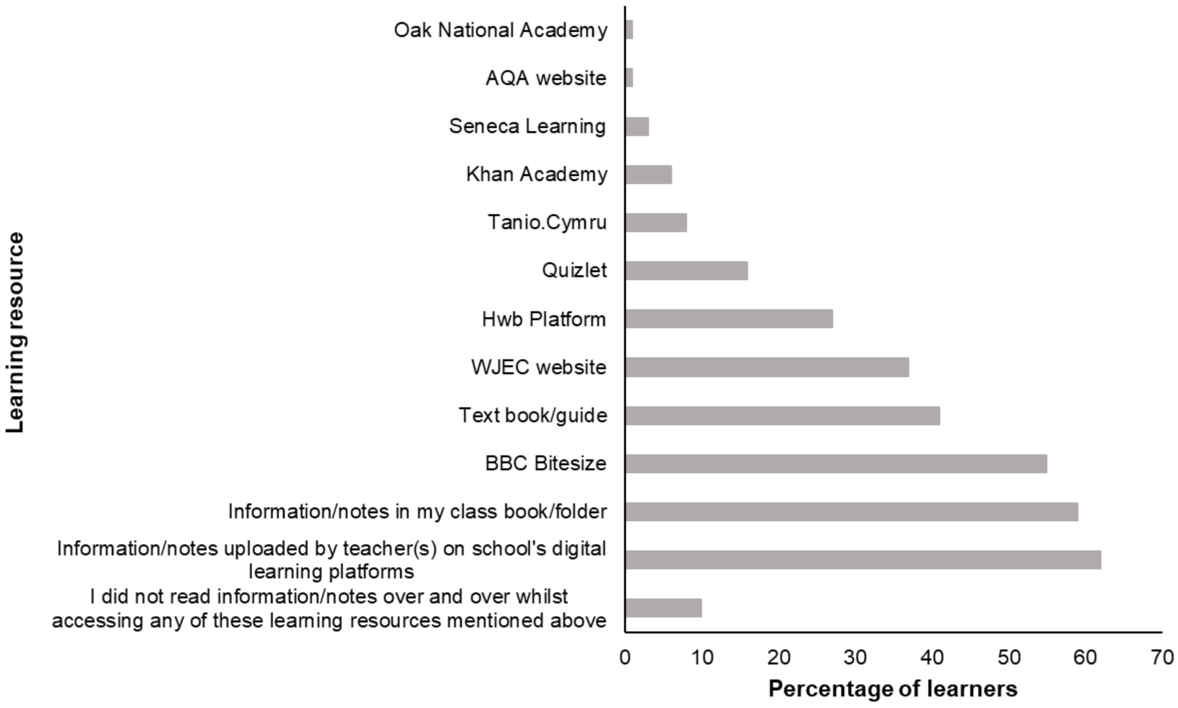


Figure E. 5 *Percentage of learner responses to the survey question, "Since the start of the COVID-19 pandemic until the present day, for any of the learning resources listed below have you* ***made notes and/or summarised information*** *whilst accessing any of these learning resources for schoolwork, study and/or revision at home?"*

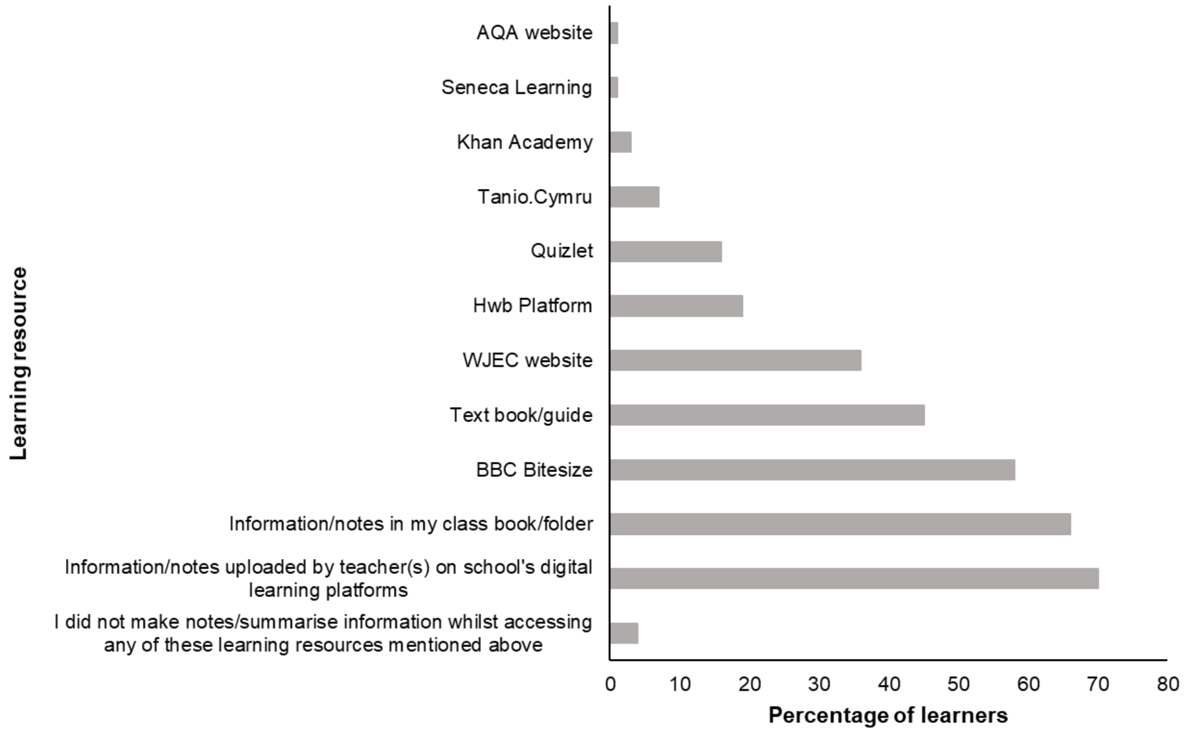


Figure E. 6 *Percentage of learner responses to the survey question, "Since the start of the COVID-19 pandemic until the present day, for any of the learning resources listed below have you used* ***spaced practice*** *whilst accessing any of these learning resources for schoolwork, study and/or revision at home?"*

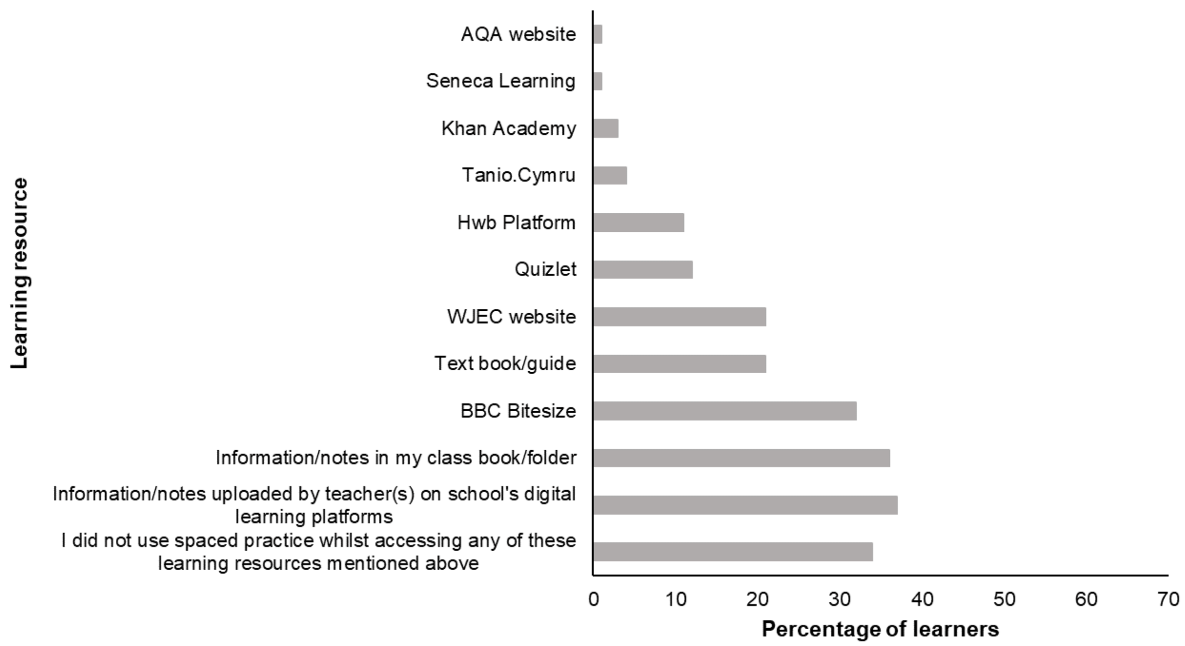


Figure E. 7 *Percentage of learner responses to the survey question, "Since the start of the COVID-19 pandemic until the present day, for any of the learning resources listed below have you used* ***retrieval practice*** *whilst accessing any of these learning resources for schoolwork, study and/or revision at home?"*

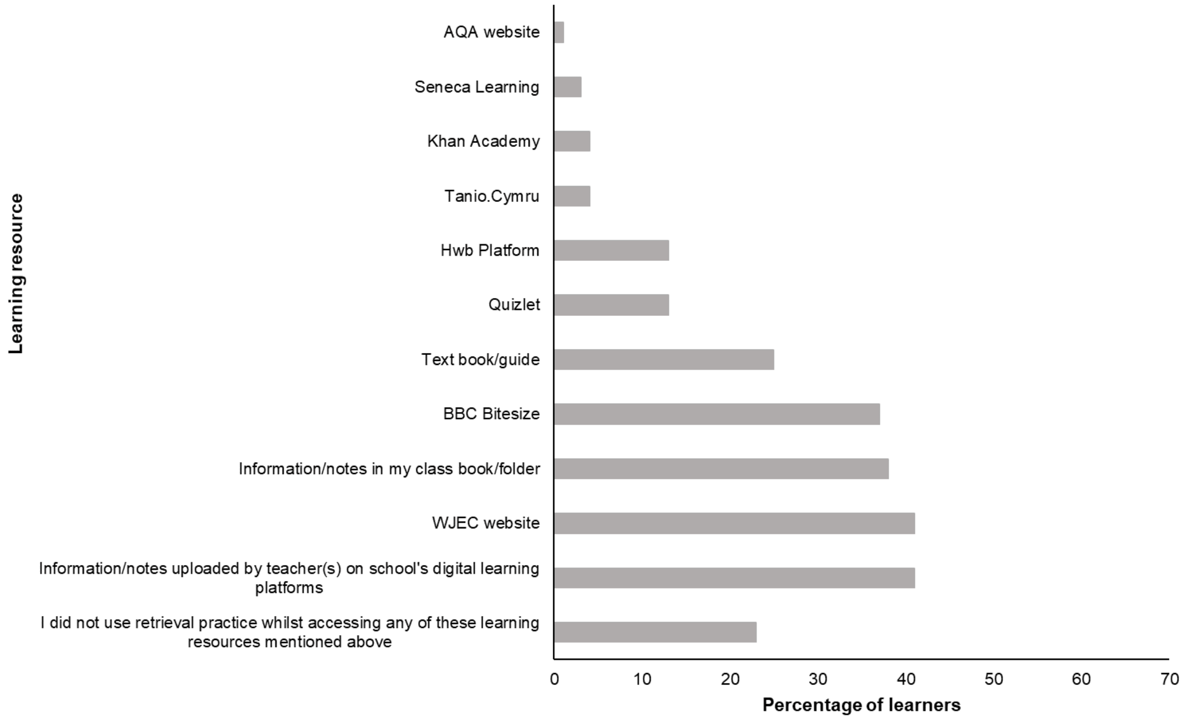


Figure E. 8 *Percentage of learner responses to the survey question, "Since the start of the COVID-19 school pandemic until the present day, for any of the learning resources listed below have you used* ***interleaved practice*** *(i.e., organising your study time so that you mix different kinds of problems or topics within a single study session), whilst accessing any of these learning resources for schoolwork, study and/or revision at home?"*

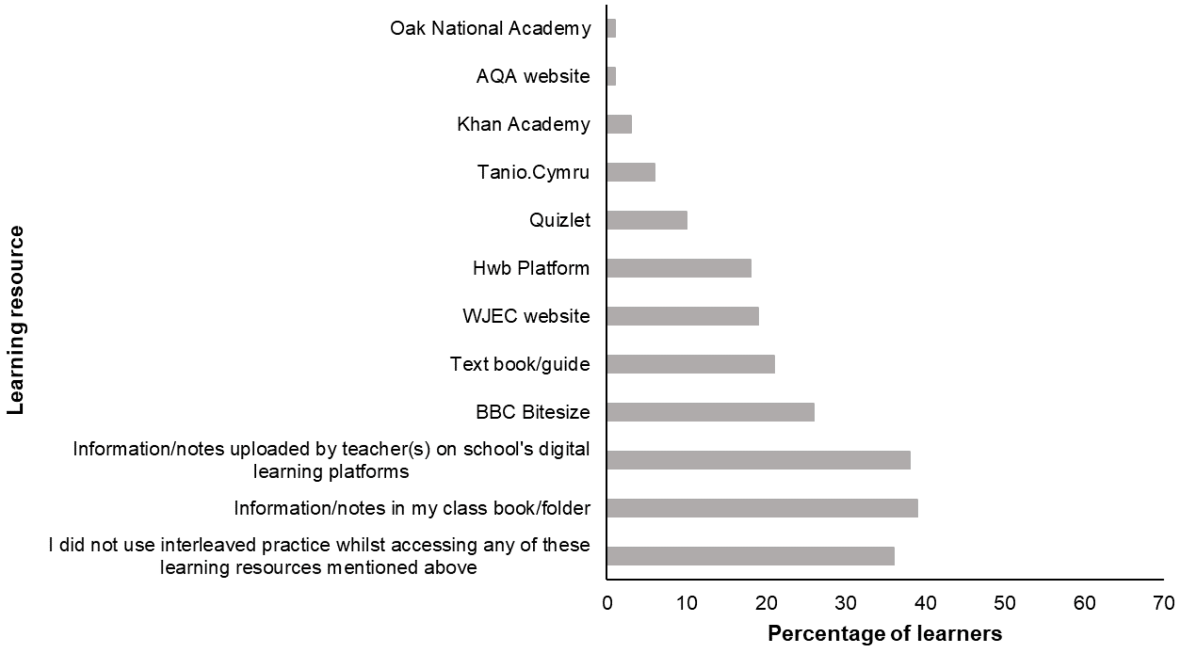
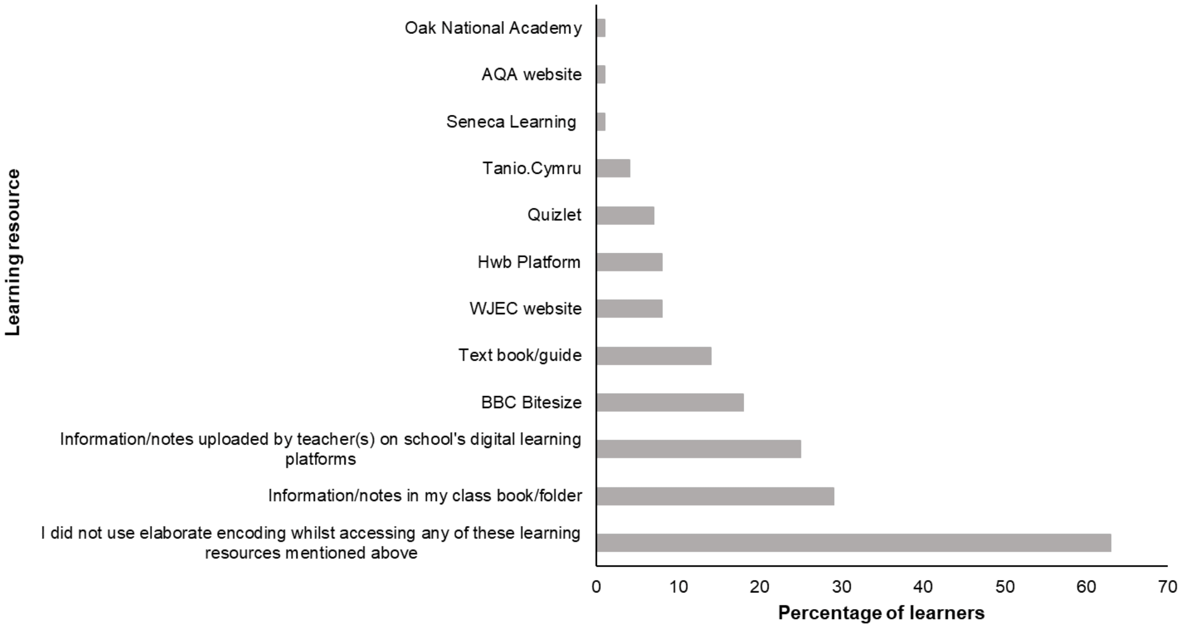


Figure E. 9 *Percentage of learner responses to the survey question, "Since the start of the COVID-19 pandemic until the present day, for any of the learning resources listed below have you used* ***elaborate encoding****, whilst accessing any of these learning resources for schoolwork, study and/or revision at home?"*



What influence did the pandemic have on learners' understanding of the effectiveness of learning strategies and study resources?

We asked learners about what they understand to be the most and least effective learning strategies for independent work. We asked learners to think about the efficacy of common learning strategies and rank the effectiveness of the strategies for learning schoolwork, study and/or revision (Table E.3). We asked learners to rate how effective they thought each strategy was for independent work. Learner ratings of the effectiveness were made on a 5-point scale, from not at all helpful (1) to extremely helpful (5), and the option 'I am not sure' was also included in this question. Table E.3 shows the eleven learning strategies and the weighted percentage scores for learners' ratings of strategy effectiveness, arranged from most to least helpful.

The learning strategy that scored most highly as being effective was making notes and/or summarising information, this strategy was categorised as a lower utility strategy by Dunlosky et al. (2013). Retrieval practice categorised as having higher utility by Dunlosky et al. (2013) for enhancing learning also scored highly as being effective. The survey results indicate that learners do not have an accurate understanding about the effectiveness of some common learning strategies.

Table E. 3 *Weighted percentage scores for learner responses to the survey question, "How effective do you think the following learning strategies are for schoolwork, study and/or revision?"*

Learning strategy[a]	**I am not sure**	**Extremely helpful**	**Very helpful**	**Moderately helpful**	**Slightly helpful**	**Not at all helpful**
	% (SE)	***% (SE)***	***% (SE)***	***% (SE)***	***% (SE)***	***% (SE)***
Making notes and/or summarising information **Utility rating: Low support**	1.3 (1.3)	38.7 (5.9)	24.4 (5.0)	23.7 (5.1)	6.3 (2.7)	5.6 (2.8)
Retrieval practice **Utility rating: High support**	6.9 (3.0)	43.1 (5.9)	15.0 (4.3)	11.2 (3.8)	7.5 (3.0)	16.3 (4.4)
Using flashcards	2.5 (1.8)	24.6 (5.3)	31.6 (5.7)	20.9 (4.8)	10.2 (3.5)	10.1 (3.7)
Spaced practice **Utility rating: High support**	10.0 (3.4)	17.5 (4.5)	23.7 (5.1)	20.6 (5.0)	17.5 (4.5)	10.6 (3.6)
Watching videos on the subject topic	5.7 (2.8)	22.8 (5.1)	19.0 (4.7)	26.6 (5.3)	16.5 (4.4)	9.5 (3.5)
Reading information/notes over and over	3.8 (2.2)	18.2 (4.5)	26.8 (5.5)	22.5 (4.9)	18.1 (4.6)	10.6 (3.6)

Learning strategy[a]	**I am not sure**	**Extremely helpful**	**Very helpful**	**Moderately helpful**	**Slightly helpful**	**Not at all helpful**
	% (SE)	***% (SE)***	***% (SE)***	***% (SE)***	***% (SE)***	***% (SE)***
Utility rating: Low support						
Using mind maps	1.3 (1.3)	17.5 (4.5)	26.9 (5.3)	24.3 (5.2)	24.4 (5.1)	5.6 (2.8)
Highlighting or underlining information/text **Utility rating: Low support**		11.8 (4.0)	17.5 (4.5)	39.4 (5.8)	25.6 (5.2)	5.6 (2.8)
Listening to audio on the subject topic	9.5 (3.5)	10.8 (3.7)	15.8 (4.5)	17.7 (4.6)	24.0 (5.2)	22.2 (5.0)
Elaborate encoding	24.4 (5.1)	10.0 (3.4)	13.7 (4.3)	9.4 (3.4)	21.9 (4.9)	20.6 (4.8)
Interleaved practice **Utility rating: Moderate support**	10.6 (3.6)	7.5 (3.0)	15.7 (4.2)	30.5 (5.6)	16.3 (4.4)	19.4 (4.7)

Note. Learning strategies are arranged from most to least helpful. [a] The six learning strategies categorised by Dunlosky et al. (2013 as high, moderate and low support we evaluated in the current study are presented alongside the utility rating for their effectiveness in enhancing learning. Five additional learning strategies identified in the literature and in our previous work were also included (*using flashcards*, *using mind maps* and *elaborate encoding, listening to audio on the subject topic, watching videos on the subject topic*), although we do not include a utility rating for these two strategies because these were not evaluated by Dunlosky et al. (2013).

Next, we asked learners to think about the efficacy of common study resources and rank the effectiveness of the resources for learning schoolwork, study and/or revision (Table E.4). We asked learners to rate how effective they thought each study resource was for independent work. Learner ratings of the effectiveness were made on a 5-point scale, from not at all helpful (1) to extremely helpful (5), and the option 'I am not sure' was also included in this question. Table E.4 shows the twelve study resources and the weighted percentage scores for learners' ratings of the perceived efficacy of the resources for independent work, arranged from most to least helpful.

The study resource that scored most highly as being effective was information/notes in their class book/folder. Two additional study resources were also scored highly as being effective, including text book/guide and information uploaded by teacher(s) on school learning platforms. Online study resources such as Seneca learning and Oak National Academy were scored as being less effective by learners. Seneca learning is an online learning resource developed by researchers and is based on using effective learning strategies. However, our survey results also showed that learners were unsure about the effectiveness of these resources.

Table E. 4 *Weighted percentage scores for learner responses to the survey question, "How effective do you think the following learning resources are for schoolwork, study and/or revision?"*

Learning resource	I am not sure	Extremely helpful	Very helpful	Moderately helpful	Slightly helpful	Not at all helpful
	% (SE)	*% (SE)*	*% (SE)*	*% (SE)*	*% (SE)*	*% (SE)*
Information/notes in my class book and/or folder	5.1 (2.5)	34.6 (5.8)	29.5 (5.5)	19.9 (4.9)	2.6 (1.8)	8.3 (3.3)
Text book/guide	3.9 (2.2)	34.6 (5.8)	26.3 (5.3)	17.3 (4.5)	7.7 (3.4)	10.2 (3.7)
Information uploaded by teacher(s) on school learning platform	9.0 (3.3)	20.4 (5.1)	26.9 (5.5)	25.1 (5.1)	9.0 (3.3)	9.6 (3.5)
BBC Bitesize	1.3 (1.3)	28.6 (5.3)	28.5 (5.4)	23.3 (5.3)	3.8 (2.2)	14.5 (4.3)
WJEC website	15.4 (4.2)	19.2 (4.9)	23.7 (5.3)	10.9 (3.9)	11.6 (3.7)	19.3 (4.7)
Hwb Platform	15.6 (4.4)	16.3 (4.4)	20.2 (4.8)	23.3 (5.3)	6.5 (2.9)	18.1 (4.8)
Quizlet	10.3 (3.5)	12.9 (3.9)	9.6 (3.5)	26.9 (5.5)	16.1 (4.3)	24.3 (5.4)
Seneca Learning	32.9 (5.8)	9.9 (3.6)	4.0 (2.3)	5.9 (2.9)	9.2 (3.4)	38.1 (6.0)
Tanio.Cymru	40.3 (6.0)	5.8 (2.9)	1.3 (1.3)	5.2 (2.6)	6.5 (2.9)	40.8 (6.1)
AQA website	41.0 (6.0)	3.2 (2.3)	6.5 (3.2)		7.1 (3.1)	42.2 (6.0)

Learning resource	I am not sure	Extremely helpful	Very helpful	Moderately helpful	Slightly helpful	Not at all helpful
	% (SE)	***% (SE)***	***% (SE)***	***% (SE)***	***% (SE)***	***% (SE)***
Khan Academy	42.3 (6.0)	1.3 (1.3)		5.8 (3.2)	8.4 (3.4)	42.2 (6.0)
Oak National Academy	44.2 (6.0)	1.3 (1.3)		1.9 (1.9)	6.5 (2.9)	46.0 (6.1)

Note. Learning resources are arranged from most to least helpful.

What influence did the pandemic have on learners' knowledge of the benefits of some commonly used and more versatile learning strategies?

We asked learners what they understand about the effectiveness of some common learning strategies, including retrieval practice, spaced practice, using flashcards and mind maps. We asked learners to select the primary reason for why they might use each of these strategies from a choice of responses presented to them. This information provides an insight into learners' awareness of the advantage of using retrieval and spaced practice as effective learning strategies. Moreover, strategies such as retrieval practice, using mind maps and using flashcards are more versatile strategies in terms of *how* they can be used because they can be used in more than one way. For example, learners might use flashcards as a retrieval practice activity (an effective learning strategy) or as a repeated reading approach (a less effective learning strategy). It was therefore important for us to understand how learners were using these more versatile strategies and whether learners were maximising on their potential. Moreover, we asked learners about their knowledge of spaced practice twice, in a different way.

Table E.5 shows learners knowledge of the benefits of retrieval practice, spaced practice, using flashcards and mind maps as learning strategies and Table E.6 shows learners knowledge of the benefits of spaced practice measured using a different question style.

Retrieval practice

Around half (49.3%) of the learners reported that retrieval practice would help them to assess their learning by identifying what they know and do not know (Table E.5). A minority (29.7%) of the learners reported that they would use retrieval practice as an effective learning strategy. This finding suggests that most learners were not aware of the advantage of using retrieval practice as a learning strategy when studying/revising.

Spaced practice

Half (53.3%) of the learners reported that spacing practice would have helped them to learn and remember information when studying/revising, suggesting that learners understand that spacing is beneficial for learning (Table E.5). We measured knowledge of the spacing advantage in a different way, and findings similarly showed half (51.3%) of the learners endorsed the long-term benefits of distributing study sessions. Few (16.2%) believed that studying in only one session was superior, and a minority (32.4%) believed that both strategies were equally effective in promoting long-term retention. This finding suggests that most learners were aware that spacing is beneficial for learning (Table E.6).

Flashcards

Our survey results in Table E.5 showed that most of the learners (35.8%) reported that using flashcards would help them to practise bringing the answer to their mind, suggesting that learners were using flashcards in an effective way as a retrieval practice activity / where learners practise recall of the answer. A minority (27.8%) of the learners reported that using flashcards would allow them to read information over and over, this is a less effective learning approach. This suggests that some learners might not understand that flashcards are a versatile study tool and can be used as a retrieval practice activity where learners read a question and then practise recall of the answer.

Mind maps

We asked learners to select a primary reason for why they might use mind maps to study/revise information learnt in school. Table E.5 showed that a minority (31.0%) of the learners reported that using mind maps would help them to identify the main topic and link this to related topics, with words that make sense to them. A similar proportion of learners (29.8%) reported that using mind maps would allow them to read information over and over, which is a less effective strategy.

Table E. 5 *Weighted percentage scores for learners' knowledge of the benefit for using retrieval practice, spaced practice, flashcards and mind maps.*

Learning strategy	Response option	% [CI]
Retrieval practice	Using retrieval practice when I study/revise will help me to know how well I have learned the information.	49.3 [37.2, 61.6]
	Using retrieval practice when I study/revise will help me to learn and remember the information	29.7 [19.7, 42.2]
	I do not think using retrieval practice when I study/revise will help me learn and remember the information.	20.9 [12.6, 32.8]
Spaced practice	Spacing out my study/revision sessions over multiple days/weeks will help me to learn more information.	22.7 [14.1, 34.4]
	Spacing out my study/revision sessions over multiple days/weeks will help me to learn and remember the information.	53.3 [40.9, 65.4]
	I do not think spacing out my study/revision sessions over multiple days/weeks will help me learn and remember the information.	24.0 [15.0, 36.2]
Flashcards	Using flashcards when I study/revise will help me to learn because it allows me to read the information over and over.	27.8 [18.3, 39.8]

Learning strategy	Response option	% [CI]
	Using flashcards when I study/revise will help me to learn because it allows me to practise bringing the answer to my mind.	35.8 [24.9, 48.4]
	Using flashcards when I study/revise will me to learn because it helps to break up the information into smaller amounts to practise.	22.9 [13.8, 35.4]
	I do not think using flashcards when I study/revise will help me learn the information.	13.5 [7.0, 24.5
Mind maps	Using mind maps when I study/revise will help me to learn because it allows me to read the information over and over.	29.8 [19.9, 42.0]
	Using mind maps when I study/revise will help me to learn because it allows me to practise bringing the information to my mind.	23.7 [14.7, 35.7]
	Using mind maps when I study/revise will help me to identify the main topic and link this to related topics, with words that make sense to me.	31.0 [20.7, 43.7]
	I do not think using mind maps when I study/revise will help me learn the information.	15.5 [8.4, 27.0]

Table E. 6 Weighted percentage scores for learners' knowledge of the benefit for using spaced practice (i.e., the spacing effect).

	Learning strategy (response option)	% [CI]
Spaced practice	Studying the material in multiple sessions of shorter duration	51.3 [39.1, 63.4]
	Studying the material in one longer session	16.2 [9.0, 27.5]
	Both of the strategies mentioned above are equally effective	32.4 [22.0, 44.9]

Note. We evaluated learners' awareness of spaced practice using two different questions in the present study.

How much time did learners invest towards school work and independent study?

We asked learners about how much time they spent on independent work, including schoolwork and independent study during the COVID-19 school closures. Schoolwork included any work learners were given to complete by their school teachers, and independent study is any work that learners set themselves to do and importantly does not include any work assigned by school teachers. Table E.7 shows the weighted percentage of learners reporting the various number of hours of schoolwork and the number of hours of independent study. Table E.7 shows that around half (41.4%) of the learners spent more than seven hours a week on schoolwork. The number of hours learners reported spending on independent study during the school closures varied between none (11.1%) and more than 7 hours (11.7%).

Table E. 7 *Weighted percentage scores for learner responses to the survey questions, "During the COVID-19 pandemic when you were learning at home all the time and did not go to school, how many hours of schoolwork did you do at home?" and, "During the COVID-19 pandemic when you were learning at home, how many hours of independent study did you do at home when your school was closed?"*

	Number of hours a week spent on schoolwork	**Number of hours a week spent on independent study**
	% (SE)	***% (SE)***
None	2.5 (1.7)	11.1 (3.8)
Less than 1	5.0 (2.4)	16.7 (4.3)
1 to 2	8.6 (3.4)	13.6 (4.1)
2 to 3	7.4 (3.0)	12.9 (4.1)
3 to 4	8.0 (3.5)	14.2 (4.1)
4 to 5	8.7 (3.2)	8.7 (3.2)
5 to 6	10.5 (3.8)	6.8 (3.0)
6 to 7	8.0 (3.2)	4.3 (2.5)
More than 7	41.4 (5.8)	11.7 (4.0)

What influence did the COVID-19 pandemic have on learners' confidence in using digital learning platforms?

We asked learners how they felt about using digital learning platforms, from a list of digital learning platforms that were provided by schools in Wales in response to the COVID-19 pandemic. We asked learners to rate how confident they felt about the various digital learning platforms at the start of the COVID-19 school closures and at the present time of completing the ERaSSQ the survey (April-May 2022). Learner ratings of their confidence in using digital learning platforms were made on a 5-point scale, from not confident at all (1) to extremely confident (5), and the option ‘our school / we did not use this’ was also included in this question.

Table E.8 shows the six digital learning platforms and the weighted percentage scores for learners’ ratings of their confidence in using the digital learning platforms at the start of the COVID-19 school closures and at the present time of completing the ERaSSQ survey. Our survey results showed that at the start of the COVID-19 school closures when learners started completing schoolwork from home, learners were less confident with using all the listed digital learning platforms such as *Hwb Platform, Microsoft Teams, Google Classroom, Moodle* and *Show My Homework* compared with the present time of completing the survey. Learners' confidence with using the six digital learning platforms increased at different rates for the various platforms (Table E.8). The digital learning platform learners scored most highly as feeling confident in using at the present time of completing the survey compared with the start of the COVID-19 schools closures was *Microsoft Teams*. There was also an increase in confidence with using Welsh Government’s digital learning platform *Hwb*. However, the learners’ ratings of low confidence with using *Hwb Platform* did not decrease very much (same with others?). The digital learning platforms that scored highly as not being used were *Google Classroom* and *Show my homework*.

Table E. 8 *Weighted percentage scores for learner responses to the survey questions, "At the start of the COVID-19 school closures when you started home learning, how confident did you feel about using the following digital learning platforms" and, "How confident do you now feel about using the following digital learning platforms?"*

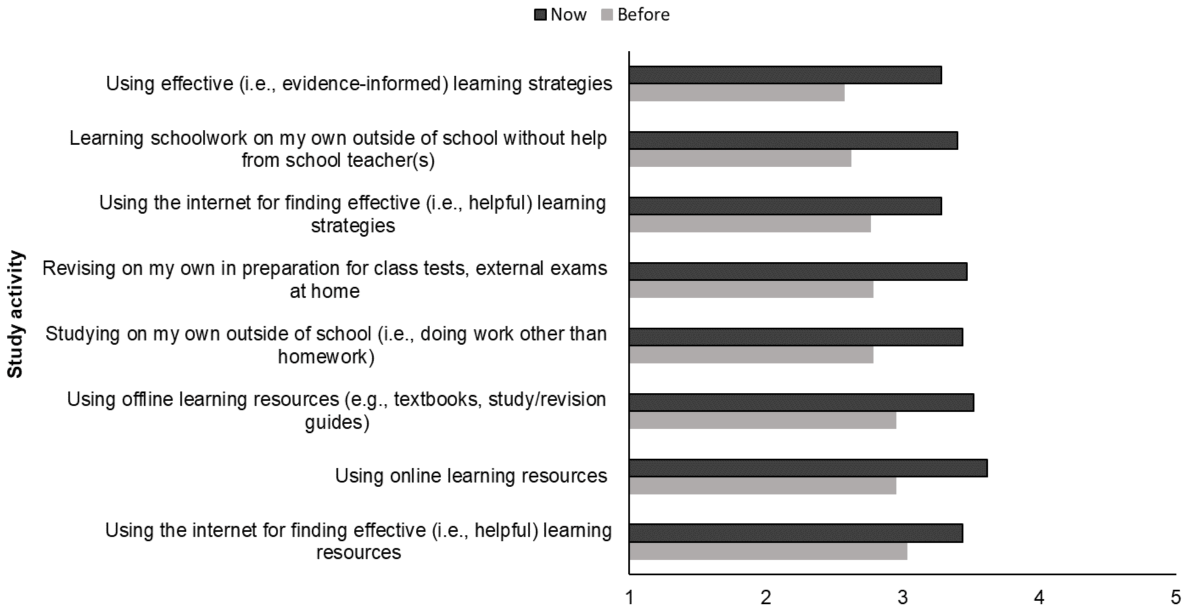
Learning platform	Not confident at all	Slightly confident	Somewhat confident	Very confident	Extremely confident	Our school / We did not use this
	% (SE)	*% (SE)*	*% (SE)*	*% (SE)*	*% (SE)*	*% (SE)*
Hwb Platform **Before**	13.7 (4.1)	14.9 (4.4)	20.6 (5.0)	28.8 (5.3)	15.7 (4.2)	6.3 (2.7)
Hwb Platform **Now**	10.5 (3.6)	14.8 (4.4)	7.4 (3.0)	22.8 (5.1)	35.8 (5.7)	8.7 (3.2)
Microsoft Teams **Before**	6.2 (3.1)	23.1 (5.1)	23.8 (5.0)	20.6 (4.8)	22.5 (4.9)	3.8 (2.2)
Microsoft Teams **Now**	3.1 (2.2)	8.0 (3.2)	10.5 (3.6)	21.6 (4.9)	55.5 (5.9)	1.2 (1.2)
Google Classroom **Before**	16.3 (4.4)	10.6 (3.6)	6.3 (2.7)	14.9 (4.4)	15.7 (4.2)	36.2 (5.8)
Google Classroom **Now**	15.1 (4.3)	9.4 (3.5)	9.4 (3.5)	13.2 (4.2)	15.8 (4.3)	37.1 (5.8)

Learning platform	**Not confident at all**	**Slightly confident**	**Somewhat confident**	**Very confident**	**Extremely confident**	**Our school / We did not use this**
	% (SE)	***% (SE)***	***% (SE)***	***% (SE)***	***% (SE)***	***% (SE)***
Moodle **Before**	22.5 (4.9)	17.5 (4.7)	17.5 (4.5)	16.9 (4.5)	9.4 (3.4)	16.3 (4.4)
Moodle **Now**	21.6 (4.9)	10.5 (3.6)	11.1 (3.8)	14.2 (4.2)	26.6 (5.2)	16.1 (4.3)
Show my homework **Before**	20.0 (4.9)	9.4 (3.4)	10.6 (3.6)	13.1 (4.0)	16.3 (4.4)	30.6 (5.5)
Show my homework **Now**	17.2 (4.6)	5.0 (2.4)	8.7 (3.2)	16.6 (4.5)	22.3 (4.9)	30.2 (5.5)

What influence did the COVID-19 pandemic have on learners' confidence towards independent learning?

We asked learners how they felt about undertaking independent study from a list of different study activities. We asked learners to rate how confident they felt about each independent learning activity at the start of the COVID-19 school closures and at the time of completing the survey (April-May 2022). Learner ratings of the study activities were made on a 5-point scale, from not confident at all (1) to extremely confident (5). Figure E.10 shows how confident learners felt about undertaking each independent learning activity at the start of the COVID-19 school closures and at the present time of completing the survey (higher weighted mean scores indicate learners rated higher confidence in undertaking the activity). The weighted percentages of learners reporting the various frequencies for their confidence (in undertaking) per study activity are presented in Table S.1 (see Appendix S). A clear improvement on learners' confidence in undertaking the listed study activities emerged with respondents giving a higher rating to all the study activities at the present time of completing the survey compared to at the start of the COVID-19 school closures (Figure E.10). Our results showed learners rated feeling *slightly confident* in undertaking most of the listed study activities at the start of the COVID-19 school closures (Figure E.10). The study activity learners scored most highly as feeling confident in undertaking at the start of the school closures was *using the internet for finding effective (i.e., helpful) learning resources* and learners rated feeling *somewhat confident* in undertaking this activity. Learners' confidence in undertaking the independent study activities increased with learners giving a higher confidence rating to all the study activities at the present time of completing the survey (Figure E.10). Our results showed learners rated feeling either *somewhat* or *very confident* in undertaking each independent activity.

Figure E. 10 *Weighted mean scores ($\bar{x}$) for learner responses to the survey questions, "At the start of the COVID-19 school closures, how confident did you feel about each of the following aspects of learning" and, "How confident do you now feel about each of the following aspects of learning"?*



Note. Learners' ratings of how confident they felt about each independent study activity at the start of the COVID-19 school closures and at the time of completing the survey was made on a 5-point scale, from not confident at all (1) to extremely confident (5). Higher scores indicate that the learners rated feeling more confident in undertaking the study activities.

Where does learners' knowledge of learning strategies and study resources come from?

We asked learners where their knowledge of learning strategies and study resources came from. We asked learners to identify the source(s) of their knowledge on learning strategies and study resources from a list of relevant sources. Table E.9 shows the percentage of learners reporting the various sources of their knowledge of strategies and the various sources of their knowledge of resources. Our survey results in Table E.9 indicate that many learners identified their 'school teacher' as the source of knowledge on learning strategies and study resources. Half reported that their knowledge of learning strategies and study resources were derived 'online' (Table E.9). Similarly, half identified their 'friend(s)/peers' as the source of their knowledge on learning strategies and study resources (Table E.9). A minority reported that their knowledge of learning strategies and study resources were derived from 'parents/carers'.

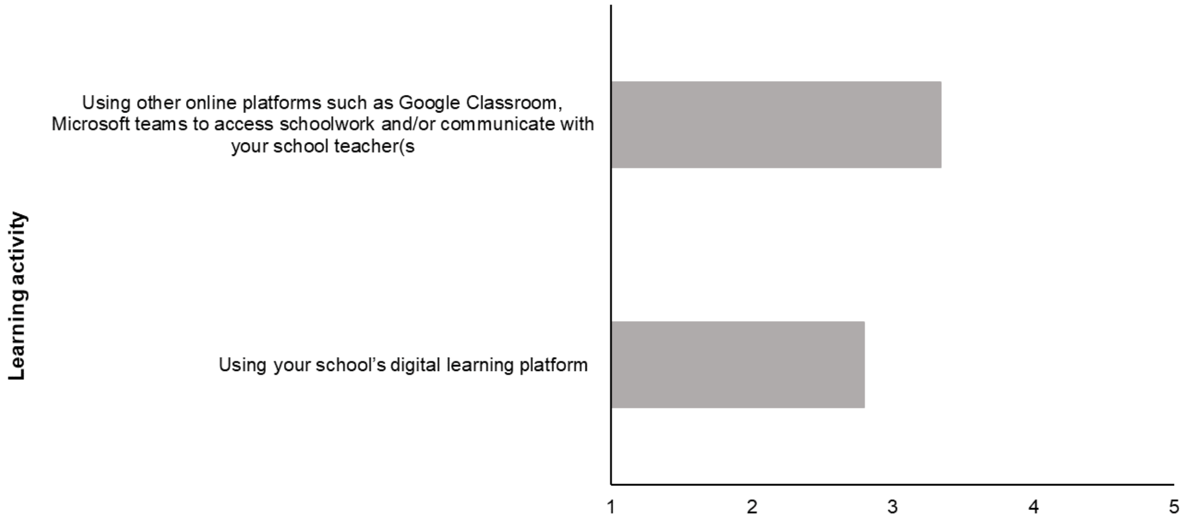
Table E. 9 *Percentage scores for learners' reporting where does their knowledge of learning strategies and study resources come from*.

Source	**Learning strategy**	**Learning resource**
	%	**%**
School teacher(s)	83	82
Online (e.g., learning resources, social media)	58	59
Friend(s)/peers	53	56
Parents/carers	40	35
School study/revision tutor	15	15
Private tutor(s)	8	8
School study/revision support centre	7	3

How helpful was the support from schools with home learning?

We asked learners about the support provided from schools to help learners with independent work. We asked learners to rate how helpful was the support provided from schools with home learning. Learner ratings of the support from schools for home learning activities were made on a 5-point scale, from not at all helpful (1) to extremely helpful (5). Figure E.11 shows learners ratings of the helpfulness of the support provided from schools with home learning (higher weighted mean scores indicated that the learners rated the support from schools as more helpful). The weighted percentages of learners reporting the various frequencies for the support from school per home learning activity are presented in Table S.2 (see Appendix S). Learners rated the support received from schools with home learning activities such as using internal and external digital learning platforms as being moderately helpful (Figure E.11).

Figure E. 11 *Weighted mean scores for learner responses to the survey question, "During the COVID-19 school closures, how helpful was the support you received from your school for the following aspects of home learning"?*



Note. Learners' ratings of how helpful the support provided from schools with home learning was made on a 5-point scale, from not at all helpful (1) to extremely helpful (5). Higher scores indicate that the learners rated the support provided from schools for the learning activities as more helpful.

Is there a demand for information about evidence-informed learning strategies and/or study resources?

We asked learners whether there is a need to provide additional information and support on the use of evidence-informed learning strategies and study resources. We asked learners whether they should be provided with information on effective learning strategies and study resources and also whether learners would be interested in receiving such information. Our survey results showed many learners (71%) were interested in receiving information about effective learning strategies and study resources to help them with independent learning (Table E.10). In addition, many learners (82%) would welcome information about effective learning strategies and study resources to support their independent learning in the event of future emergencies (Table E.10).

Table E. 10 *Weighted percentage scores for learner responses to the survey questions about availability and demand for support with study/revision.*

Survey item	**Response option**	***%***	***SE***
Do you think that you should be provided with information about effective learning strategies and/or learning resources to help with schoolwork, study/revision in the event of any future school closures?	Yes No	82 17	4.9 4.9
Would you be interested in receiving information about effective (i.e., evidence-informed) learning strategies	Yes	71	5.6

Survey item	Response option	*%*	*SE*
and/or learning resources that will help you to learn schoolwork, study/revise effectively?	No	28	5.6

Discussion

In this report we used a multistage clustered sample design to evaluate the impact of the COVID-19 pandemic on the independent study practice of learners aged 14–15 and 16–17 years in Wales. We explored learners' use and understanding of common learning strategies and study resources for independent work, study and/or revision since the start of the school closures caused by the COVID-19 pandemic until the present day. In addition, we report on the time learners invested towards schoolwork and independent study, and how confident they were in using digital learning platforms and independent study activities at the start of the COVID-19 pandemic and at present. Importantly, we also report on learners' source of knowledge on learning strategies and study resources, as well as the support learners received from schools for independent work. In the following section we discuss our findings on each of these aspects.

Use of study resources and learning strategies

Our results showed that the study resources provided by schools were most frequently used by learners for independent work whilst at home, including *information/notes in their class book/folder* and *information notes uploaded by teacher(s) on the school's digital learning platform*. BBC Bitesize was a frequently used online study resource by learners and the Oak National Academy (a resource developed by teachers in England in response to the COVID-19 pandemic) was the least frequently used online study resource. These findings align with the outcomes of the WISERD (2020) survey. In the present study we also assessed learners' understanding of the effectiveness of study resources and found that the newly developed Oak National Academy resource was ranked among the least effective study resources by learners. It is important to note that our survey results also showed that 32.9 per cent of learners reported that they were unsure about the effectiveness of this resource and this might explain why more learners chose not to use the Oak National Academy resource.

In the present survey, learners reported more frequently using the Welsh Government's Hwb platform. In contrast, the WISERD survey (2020) reported that 63.6 per cent of learners reported that they had not used this national study resource. A possible explanation for this might be due to the differences in the timeline between the survey completion dates in the present study and in the WISERD survey (2020). The current study survey with school learners was completed between April and May 2022, whereas the WISERD survey with school learners was completed before the end of the 2019-20 summer term. It may be that learners were less familiar and/or less confident with using the Hwb platform when they first started using digital learning platforms for remote learning. For example, our survey also found that at the start of the COVID-19 school closures when learners started completing schoolwork from home, learners were less confident with using digital learning platforms such as *Hwb, Microsoft Teams, Google Classroom, Moodle* and *Show My Homework* compared with the present time of completing the survey. There was an increase in confidence with using Welsh Government's digital learning platform *Hwb* at the time of completing the survey in the current study (April-May 2022).

We also explored which learning strategies learners were using to help them with independent work whilst accessing the various study resources. Our findings showed that most learners were using both higher and lower utility strategies to complete tasks whilst accessing the most commonly used study resources. The lower utility learning strategies were highlighting and/or underlining information/text, reading information/notes over and over and making notes and/or summarising information for accessing information/notes uploaded by teacher(s) on their school's digital learning platforms, information/notes in their class book/folder and/or whilst using the BBC Bitesize website. We also found that learners reported using medium to higher utility strategies such as elaborate encoding, interleaved practice, and spaced practice (a higher utility strategy), less frequently. These findings align with the outcomes of previous studies which found that secondary learners mostly relied on less optimal learning strategies such as making notes, repeatedly reading information, highlighting and/or underlining information for independent work compared to more effective learning strategies including retrieval and spaced practice (Agarwal et al., 2014; Dirkx et al., 2019; Sultana et al., 2023). These findings suggest that learners' choice of strategies has not changed over recent years and, importantly, despite the need for learners to work more independently during the COVID-19 school closures, their use of learning strategies has not changed since the start of the pandemic. Our findings highlight the need for schools to continue to improve awareness about effective learning strategies and study resources.

Understanding of learning strategies and study resources

The present study has shown that learners have limited to moderate understanding of the effectiveness of commonly used learning strategies. The learning strategy that scored most highly by learners as being effective was making notes and/or summarising information (a strategy rated as lower utility by Dunlosky et al. [2013]). Learners' opinions of the effectiveness of some commonly used learning strategies indicate that they do not realise that these strategies may not be among the most effective. This suggests that learners have some mistaken beliefs about the efficacy of commonly used learning strategies, and this might explain why learners continue to use these approaches. Importantly, these findings also suggest that despite the need for learners to work more independently during the COVID-19 school closures, learners' understanding of the utility of learning strategies have not changed since the start of the COVID-19 pandemic.

Retrieval practice, categorised by Dunlosky et al. (2013) as a higher utility approach, was also rated highly by learners. However, when interpreting these findings it is important to consider that our survey also found that about half of learners reported that they would use retrieval practice as a strategy to help them assess their learning, or to help them identify what they know and or do not know rather than as an effective learning strategy. This finding suggests that most learners were not aware of the advantage of using retrieval practice as a learning strategy for independent work. This finding aligns with the outcomes of earlier studies which found that secondary learners predominantly used retrieval activities for diagnostic purposes (Agarwal et al., 2014; Sultana et al., 2023). It is possible learners might not be using retrieval practice as a learning strategy due to their experience of completing retrieval practice activities for summative purposes in school.

Half of the learners reported that spacing practice would have helped them to learn and remember information when studying and/or revising, suggesting that learners understand that spacing is beneficial for learning. Further evidence indicating awareness of the spacing advantage came from our survey question that asked learners to select a strategy that research has shown to be an effective learning approach. Similarly, we found half of the learners endorsed the option on the long-term benefits of spacing study sessions. However, in this study, fewer learners reported using spaced practice to help them learn whilst accessing various study resources. Findings from an earlier study with secondary learners in North Wales indicated that learners were aware of the spacing advantage, although these learners similarly reported using this strategy less frequently (Sultana et al., 2023). The inconsistency between learners' knowledge and utilisation of spaced practice may be partly because it is a strategy that advises on *when* to practice instead of *how* to practice. Despite the need for learners to work more independently during the COVID-19 school closures, learners' understanding of the utility of learning strategies have not changed since the start of the COVID-19 pandemic.

The study resources learners ranked as effective for independent work were information/notes in their class book/folder, text book/guide and information uploaded by teacher(s) on the school's learning platform. Online study resources such as Seneca learning and Oak National Academy were scored as being less effective by learners. Seneca learning is an online learning resource developed by researchers and is underpinned by retrieval practice methodology. Learners' ratings of the effectiveness of some learning resources suggests that they might not be fully aware of their utility. This could be in part due to their lack of experience with using online study resources prior to the school closures. These findings indicate learners would benefit from receiving more information about the utility of some study resources. Previous studies in this field with learners have been limited to exploring their use of study resources (WISERD, 2020; Mylona & Heledd, 2021). This is the first study to assess learners' understanding of the effectiveness of study resources.This study has provided an insight into learners' understanding of the utility of commonly used study resources and, importantly, the results highlight the need for educators to ensure an appropriate repository of resources are created and made available for schools and colleges.

Confidence levels towards digital learning platforms

Other factors that may have affected the ability of learners to undertake independent work include their confidence in using digital learning platforms; confidence in undertaking independent study activities; and, their ability to source knowledge on learning strategies and study resources. Findings from a study with 16–19 year old learners' experiences at the start of the pandemic indicated that although some learners were provided with digital devices, there was a lack of guidance from schools on how to use the hardware, and this was a barrier to learning (Mylona & Heledd, 2021). Our data on learners' confidence when using digital learning platforms at the start of the COVID-19 school closures shows that they were less confident when using digital learning platforms such as the *Hwb platform, Microsoft Teams, Google Classroom, Moodle* and *Show My Homework*. Our findings also show learners' confidence levels towards the same digital learning platforms improved over time, with learners now reporting higher levels of confidence in using key digital platforms such as *Hwb* and *Microsoft Teams*. Importantly, learners now report feeling more confident in using key digital learning platforms compared to the start of the COVID-19 pandemic. When interpreting these promising results, it is important to note that our survey results also showed that the percentage of learners reporting low confidence in using the *Hwb* platform did not decrease a lot. Our results show that learners would benefit from receiving more information and support/guidance about how to use key digital learning platforms such as *Hwb.*

Confidence levels towards independent study activities

At the start of the COVID-19 pandemic, learners rated feeling *slightly confident* in undertaking most of the study activities, including *using effective (evidence-informed) learning strategies*, *learning schoolwork on my own outside of school without help from school teacher(s)*, *studying on my own outside of school (i.e., doing work other than homework)*, *revising on my own in preparation for class tests/external exams at home, using the internet for finding effective (i.e., evidence informed) learning strategies), using offline learning resources (e.g., textbooks, study/revision guides), and using online learning resources.* One reason learners might have experienced challenges with learning schoolwork on their own could be due to their lack of information and guidance to help them use more effective independent study and revision skills. Similarly, a study by Morgan (2020) showed that most university learners reported that they had not utilised independent study at home prior to coming to university. After the COVID-19 pandemic, confidence levels increased for all learning activities and this is likely to have been driven by the need for learners to work independently during schools' remote learning provision during lockdown. Nonetheless, these findings highlight the need for schools to continue to improve learners' awareness about independent study and revision skills.

Efforts towards schoolwork and independent study

Our findings show that around half of the learners spent more than seven hours a week on schoolwork. In the WISERD (2020) survey most learners reported spending six to ten hours a week completing schoolwork. In the present study, we also assessed the duration of independent study learners undertook. In contrast to schoolwork, which included any work learners were given to complete by their school teachers, independent study included any work that learners set themselves and did not include any work assigned by school teachers. Results show that the number of hours learners reported spending on independent study during the school closures varied between zero to more than seven hours per week. Results from an earlier study with school learners in North Wales showed that 39.6 percent reported studying on their own for less than one hour in a typical week (Sultana et al., 2023). In addition to educating learners about more effective study resources and learning strategies, teachers also need to ensure they also teach learners about the importance of investing time for independent study and revision. Oakes and Griffin (2016) proposed one way to encourage high levels of effort is to communicate how many hours a week learners should consider investing for independent study.

Source of knowledge on learning strategies and learning resources

Many of the learners in this study reported that their knowledge of learning strategies (83.3%) and learning resources (81.5%) had derived from their school teacher(s). In this study we did not evaluate what learning strategies and/or resources school teachers might have used to promote independent learning during the school closures. Previous studies with university instructors show that university instructors promote both less- and more-effective learning strategies and have a moderate understanding about evidence-informed learning strategies (McCabe, 2018; Piza, 2018; Morehead et al., 2016). Results from an earlier study with secondary learners in North Wales showed that most learners (92.7%) reported that their science teacher(s) encouraged them to use retrieval practice, an effective learning strategy (Sultana et al., 2023). However, when interpreting these promising results, it is important to consider that we have previously found that most learners reported they would complete retrieval practice as a diagnostic tool to assess their knowledge rather than as a learning strategy. A survey with science subject leaders on their understanding and recommendation of learning strategies also showed that they would recommend retrieval activities to help learners assess their learning rather than as learning strategy (Sultana, 2023).

Parents/carers are an important source of information and guidance for learners for independent learning. In the current study, we found that a minority of learners reported that their knowledge of learning strategies (40%) and study resources (35%) were derived from 'parents/carers'. Studies on the impact of the COVID-19 pandemic show that learners benefitting from more parental guidance and support made more progress despite the COVID-19 school restrictions (Waters-Davies et al., 2021; Department for Education, 2022). These studies show that there is an important role for parents/carers to promote independent learning and effective learning strategies. Further research now needs to focus on how best to communicate this information to parents/carers.

Support from schools

The findings here show that learners rated the support received from schools for using their school's digital learning platform and using other online platforms as *moderately helpful*. Learners would welcome more information and support with independent work. Our findings also show many (71%) learners reported that they were interested in receiving information about effective learning strategies and resources to help them with independent learning. Many (82%) of the learners also reported that they should be provided with information about effective learning strategies and resources to support their independent learning in the event of future emergencies.

Strengths and limitations

We acknowledge some limitations in the current study. There was some non-response to the survey because not all sampled units, including schools and learners were observed. To attempt to more appropriately represent learners we made weighting adjustments to compensate for non-response. To correct for the non-response we weighted learners' data to use post-stratification techniques. For post-stratification our aim was to match the responding dataset to the school population data set for the number of learners in Year 10 and Year 12. However, the number of variables to build a non-response model was limited to only one, which was the total year group numbers. This was the information that we had access to for both respondents and non-respondents. It would have been helpful to have access to a wider range of information to enable us to check whether other potential variables were related to the non-response process, and there remains a possibility of some uncorrected left-over nonresponse bias in our data. We also anticipated a higher response rate for the survey and despite several reminders to schools the present study received a lower response rate than expected. There has been a decrease in response rates in general population surveys, and this might be a reason for the lower response rate observed in the current study (Luiten, Hox, Leeuw, 2020).

Recommendations

Recommendations for Welsh Government

Welsh Government should communicate the importance of independent learning skills, and provide guidance to improve teachers' knowledge of higher utility independent learning skills that learners can use in secondary and further education settings.

Welsh Government should ensure that an appropriate repository of study skill resources is made available for schools and colleges to help learners use more effective study and revision strategies across a range of subject areas.

Welsh Government should also work with the regional consortia and Estyn to ensure that schools receive appropriate guidance and best practice case studies to help embed the use of effective learning strategies in education settings.

Recommendations for middle tier organisations (i.e., Local Authorities, ESTYN, School Improvement Agencies, Qualifications Wales)

Middle tier organisations should work with Welsh Government and schools to communicate the importance of independent learning skills by providing guidance to improve teachers’ knowledge of higher utility independent learning skills to help learners in secondary and further education settings.

Middle tier organisations should monitor the implementation of independent learning intervention programmes in school and college settings. Ensure initial teacher education programmes, and support for newly qualified teachers, includes provision for understanding the importance of supporting learners to use effective independent learning skills.

Recommendations for school leaders and practitioners

Schools should work with teaching staff to more clearly exemplify effective independent study and revision strategies. Schools should also provide learners with information about how to use some of the more effective learning strategies such as retrieval and spaced practice and communicate the importance of how these strategies can be used as part of purposeful independent learning and revision.

Recommendations for future research

Our study did not evaluate parents’ and carers’ understanding of independent learning skills. Future research should be conducted with parents and carers to explore how they can promote the use of effective learning strategies at home.

Appendix F: Feasibility trial parent and carer study information letter and sheet (Chapter 4). Study documents were made available in both English and Welsh.

DATE

Dear Parent/Guardian,

Study title: *Improving Standards through Effective Revision* project (iStER).

We are writing to inform you about an important research study taking place in SCHOOL NAME aimed at improving pupils' learning in science. This work is being undertaken in collaboration with the Regional School Effectiveness and Improvement Service for North Wales (GwE). Your child is being invited to take part in this project. This letter explains why the research is being carried out and what it will involve. Please take time to read the following information carefully and if you have any questions, please ask us.

We are interested in evaluating the impact of evidence-based learning strategies that are designed to help secondary school pupils study and revise more effectively in preparation for their GCSE chemistry examinations.

We have approached your child's school and explained the purpose of the study and how it might help pupils prepare for their chemistry examinations. The school is keen to participate in the *Improving Standards through Effective Revision* project (iStER).

An overview of the project is contained in the information sheet attached to this letter. This aspect of the research study involves your child being randomly allocated to one of three study groups to enable us to compare the impact of the new strategies against current practice. All groups will complete a science assessment and pre- and post-intervention questionnaire. At the end of the project in April 2020, we will ensure that all pupils will have access to the new trial materials, and not just those randomly allocated to receive them first.

If you have any further questions pertaining to any aspect of this research, or your child's participation in it, please contact the PhD student (Fatema Sultana) undertaking this research study, (e-mail soubfb@bangor.ac.uk). If you have any concerns about the research being conducted, please contact the College Manager Mr Huw Ellis, at School of Psychology, Bangor University, Bangor, Gwynedd, LL57 2AS or email huw.ellis@bangor.ac.uk

If you are happy for your child to take part in the project, please complete and return the form enclosed with this letter. Your child's school will then liaise with the research team to organise the study programme in school.

Yours faithfully,

Fatema Sultana Prof J. Carl Hughes Dr Richard Watkins (GwE)

PARENT/GUARDIAN CONSENT FORM

(Copy to be returned to researcher)

Study title: An Evaluation of a Revision Programme for Science

I have read the information about the study and discussed this with my child.

Please tick the boxes as appropriate.

I am willing for my child to take part in the study.

I am happy for the Bangor University research team to share my child's science assessment scores with SCHOOL NAME (we will also ask your child if they are happy for the school to receive their chemistry results).

Name of child: ………………………………………………..

School: ………………………………………………..

Year group: ………………………………………………..

Signature of parent/guardian: ………………………………………………..

Date: ………………………………………………..

An Evaluation of a Revision Programme for Science

Information for parents/guardians

The Research Project: An Evaluation of a Revision Programme for Science

Your child is being invited to take part in a research project. This leaflet explains why the research is being carried out and what it will involve. Please take time to read the following information carefully and if you have any questions, please ask us.

Researchers:
Fatema Sultana (PhD student), School of Psychology, Bangor University.
Professor J Carl Hughes (Supervisor), School of Education and Human Development, Bangor University.
Dr Richard Watkins (Supervisor), GwE (Regional School Effectiveness and Improvement Service for North Wales).

What is the purpose of this research?

Your child's school is taking part in a project called: Improving Standards through Effective Revision (iStER).

According to research, the learning strategies pupils use to revise (i.e., how they learn) can have an impact on the outcomes they get. Learning strategies can be described as methods pupils can use to learn important subject information in preparation for exams. Through effective learning strategies pupils study skills can be improved. Research shows that using effective learning strategies has positive effects on academic performance essential for lifelong success.

Researchers from Bangor University and the Regional School Effectiveness and Improvement Service for North Wales (GwE) have been developing an evidence-based revision programme called *Improving Standards through Effective Revision* (iStER). The purpose of this project is to evaluate the impact of the revision programme that is designed to help secondary school pupils revise more effectively for GCSE science. The aim is to help pupils' study and revise more effectively to help them improve the standards they can achieve.

Contact details:

If you require any further information or have any questions about this study, contact:

Fatema Sultana (PhD Student)
Email: soubfb@bangor.ac.uk

Prof. Carl Hughes (supervisor)
Phone: 01248 383278
Email: c.hughes@bangor.ac.uk

Or address to the School of Psychology, Bangor University, Bangor, Gwynedd, LL57 2AS.

What am I being asked to do?

We ask you to read through the information provided about the study and decide whether you would consent to your child taking part in the project. **If you agree for your child to take part, then please sign and return the attached consent form to school.**

There will be no negative impact if you chose not to take part in the study. Similarly, you can withdraw your consent at any point by contacting a member of the research team.

Why is my child being asked to take part in this project?

Your child is being asked to take part because he/she is between the age of 14 and 16 and is studying science.

What does the project involve?

If you agree for your child to take part then he/she will receive the iStER revision programme this year. The project will also be explained to your child and we will ask for your child's agreement before commencing the teaching.
Information on the iStER revision programme and resources are detailed below.

At the start (January-February 2020) and end (April-May 2020) of the project, your child will be asked to complete a brief questionnaire and science assessment to help us gather information about your child's chemistry content knowledge and views about how they learn and/or revise, as well as basic demographic information such as gender and science group.

A member of the research team will then deliver the training session as part of the revision programme and this will last approximately 1 hour. The training session will include a presentation that is designed to teach your child about effective learning strategies. Your child will then take part in a practical session during which he/she will receive some study/revision materials alongside step-by-step instructions on how to use them in chemistry.
At the end of the project your child will be asked to complete a brief questionnaire and science assessment. This will help us evaluate the impact of the new strategies.

What does the revision programme involve?

The iStER revision programme has been developed to improve secondary pupils learning in school science (chemistry). The programme includes effective learning strategies, using retrieval practice and spacing practice, which promote deep and long-term learning. The programme also includes an effective practice and recall strategy, called the Leitner system, to help pupils to organise their learning more effectively.

Do all children take part in the project?

We want to use a group of pupils to compare the iStER revision programme with usual revision/study techniques. Some of the pupils in the trial group will be randomly selected (like tossing a coin) to receive weekly supervised iStER sessions in school. A second group of pupils will receive chemistry materials and attend weekly supervised study/revision sessions in school using their usual learning strategies. A third group of pupils will continue to study/revise as usual without attending any additional weekly sessions. All pupils, irrespective of which group they are in, will receive GCSE Chemistry revision guides.

Do all children receive the programme?

Yes. This project is using a waiting list control design. This means that the two groups of pupils who were not initially randomised to receive the iStER revision programme will receive the training and materials at the end of the study (April 2020).

Will my child's details and data be kept confidential?

Yes. All the information about participants in this study will be kept confidential and data will be anonymous and stored securely. Pupil data will not be shared with any third parties. Only members of the research team and your child's school will have access to the study data. You are free to withdraw your child's data from the study data for up to one month after the final data collection without giving a reason. After one month, the data will be anonymised. This means that your child's name will be replaced with a code and we will not be able to identify your child's information. You may withdraw from the study by directly contacting any of the researchers. If you decide to withdraw, your decision will not have a negative impact. Bangor University's Ethics Committee inspects all project proposals before work begins (Ethics approval number: 2019-16566).

Benefits for your child

Your child will benefit from the teaching of evidence based learning strategies and how to effectively regulate their independent study/revision time. In addition, your child will benefit from (the school) receiving feedback about their level of understanding of key chemistry facts and concepts. We hope this will help them improve their level of attainment in chemistry. Your child's participation will contribute to this study's broader aims to improve the science outcomes of current and future pupils in secondary schools across North Wales.

Are there any risks?

There are no obvious risks for participating in the study. A member of the research team will deliver the programme to pupils in a classroom on school site and, a member of the school team will supervise the school visits. Members of the research team are DBS certified.

What do I do next?

If you are happy for your child to take part in the project, please complete and return the form enclosed with the letter. Your child's school will then liaise with the research team to organize the revision programme in school.

Thank you very much for taking the time to read this information sheet.

Appendix G: Script for blind assessor (Chapter 4)

My name is [Name of blind assessor] and I am from Bangor University/. School name/your school is taking part in a research project and we would like you to join in. Your parents/guardians are also happy for you to join. Research is a way of finding out answers to questions. This research will help us find out about how you study/revise, and how you can improve your study/revision for chemistry using effective ways to learn.

Why have I been asked to take part?

We are inviting/asking you to take part because your school is keen to help you study/revise effectively for GCSE chemistry. We are asking pupils in Year group 10 to take part.

What will happen if I take part?

Today I will give you some questionnaires to fill in. There are three questionnaires altogether. The first questionnaire will ask you about some of the chemistry topics you have been learning in chemistry lessons. The second questionnaire will ask you about how you study/revise for chemistry, and the third questionnaire will ask about what you think and how you feel about your chemistry lessons. It will take around 1 hour and 15 minutes to fill in these questionnaires.

Will anyone know my answers?

Instead of putting your names on yours forms, we will be using codes. All the questionnaires will then be collected and stored securely.

What happens next?

We are going to arrange you into three groups. The groups do not reflect your current science set or how you are currently doing in chemistry. The groups will be put together randomly (like tossing a coin). Two of the groups will receive a revision programme starting in February and the third group will carry on as usual until the end of the project.

Will everyone receive the revision programme?

Yes, this project is using a waiting list control design. This means that if you were in the group that was not randomised to receive a revision programme, you will receive the programme at the end of the project in April 2020. You will all also receive a GCSE chemistry revision guide at the end of the project for taking part.

How do I know which group I am in?

Your form teacher will tell you which group you are in. He/she will also tell you during which lesson and in which class your first session is in.

Do I have to take part in this project?

No, it is entirely up to you decide if you want to take part. You can ask questions before choosing whether you want to join in today. You can always change your mind too and you don't have to say why.

Is this study ok to do?

Before any research projects happen it has to be checked by a group of people known as the research Ethics Committee to make sure that it is fair. This project has been checked by the Ethics Committee at Bangor University.

Will joining in help me?

It can be helpful. You will learn about effective ways to study/revise. You will also be able to find out how well you know the chemistry topics, and you can use this to improve your future learning in chemistry.

What if I don't want to take part anymore?

Just tell your teacher or the researcher. It is fine if you do not want to take part and you don't need to say why.

What if there is a problem or something goes wrong?

If you are not happy about something that happens in the study, please talk to your teacher or the researcher.

Thank you for listening – please ask me any questions.

What do I do now?

If you are happy to join this project then you can tick the first box on the front page. If you would like to find out how you do on the chemistry questionnaire please tick the second box, and if you would like the school to know how you do on the chemistry questionnaire so that they can help you to focus on improving your chemistry then please tick the third box.

Before you can begin, it is important that you know that **this is not an exam**, however, there are some rules we would like you to follow:

1. You will be filling in the questionnaires on your own.
2. Please do not speak to any other person in the room.
3. Please try to answer all the questions. If you really don't know the answer to a question, that is fine, you can leave the question blank, and move on to the next question.
4. If you don't understand a question, please put up your hand and I will come over and explain the question.
5. When you have finished please sit quietly until everyone else has also finished.

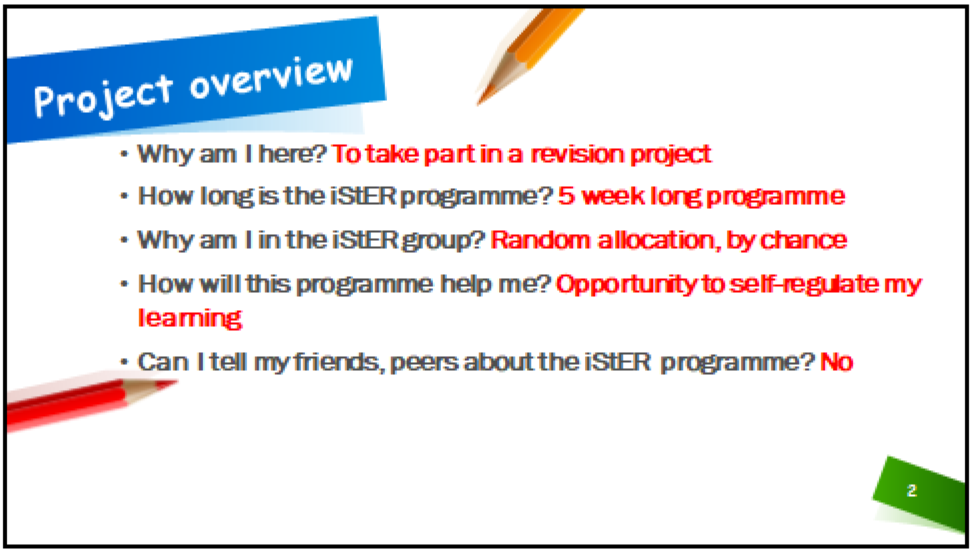
6. Remember, that this is not an exam, the scores you get will not count towards any of your school grades.

7. You will notice that there are codes on your envelopes and questionnaires. This is because we are not asking anyone to write their names on the questionnaires/ assessments. If however, anyone changed their mind later in the study, and wanted to remove their data, then you/ school can us your code and we can take out your data only instead of having to take out everyone's data.

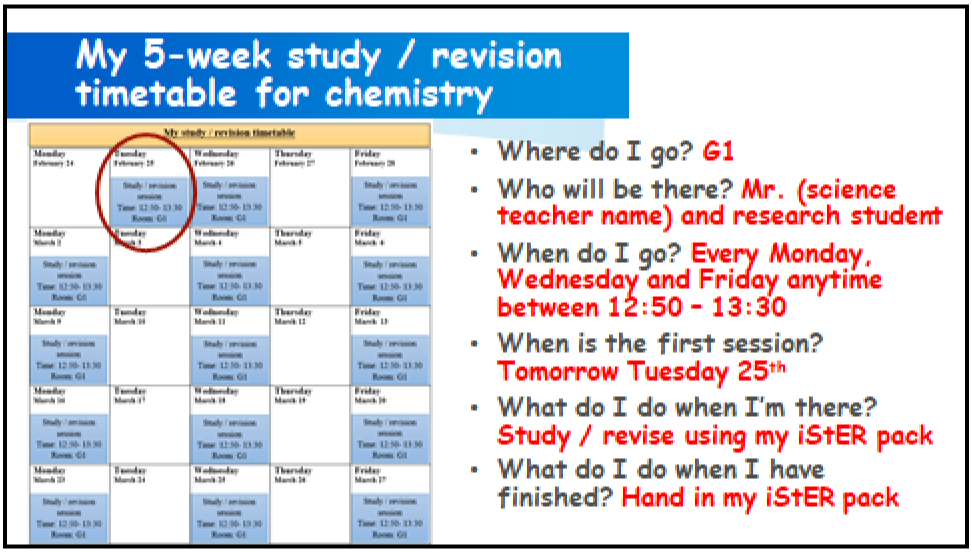
8. You can start when you are ready.

Appendix H: PowerPoint presentation training slides for iStER group (Chapter 4)

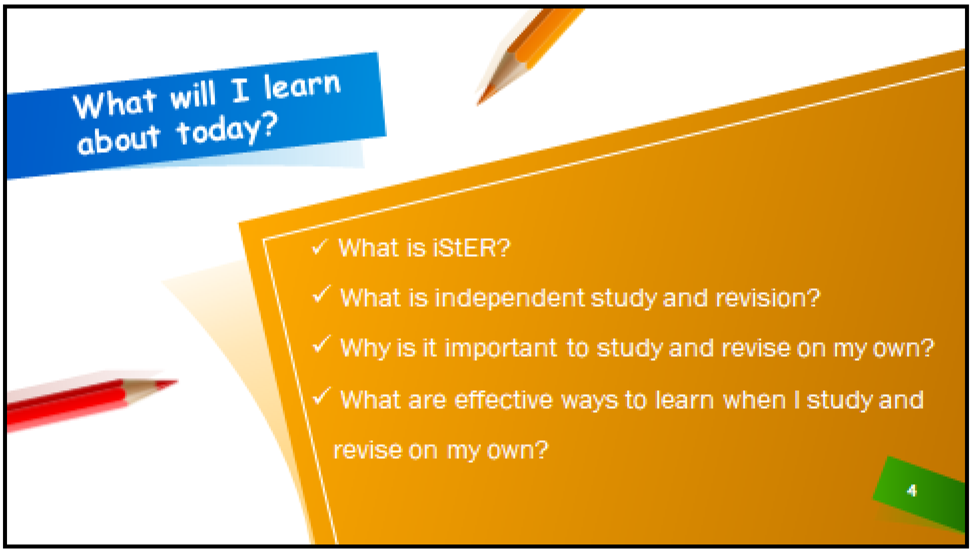
1



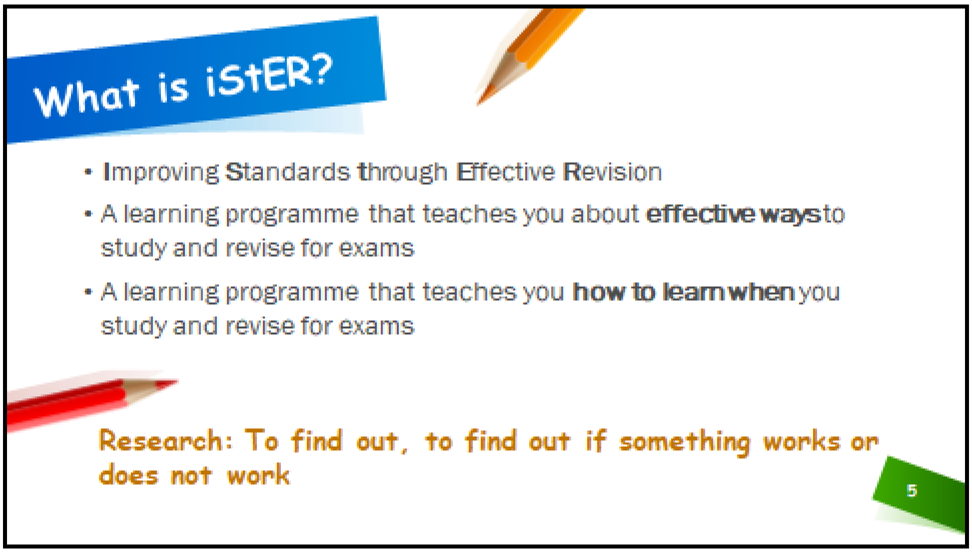
2


My 5-week study / revision timetable for chemistry
Where do I go? G1
Who will be there? Mr. (science teacher name) and research student
When do I go? Every Monday, Wednesday and Friday anytime between 12:50 - 13:30
When is the first session? Tomorrow Tuesday 25th
What do I do when I'm there? Study / revise using my iStER pack
What do I do when I have finished? Hand in my iStER pack

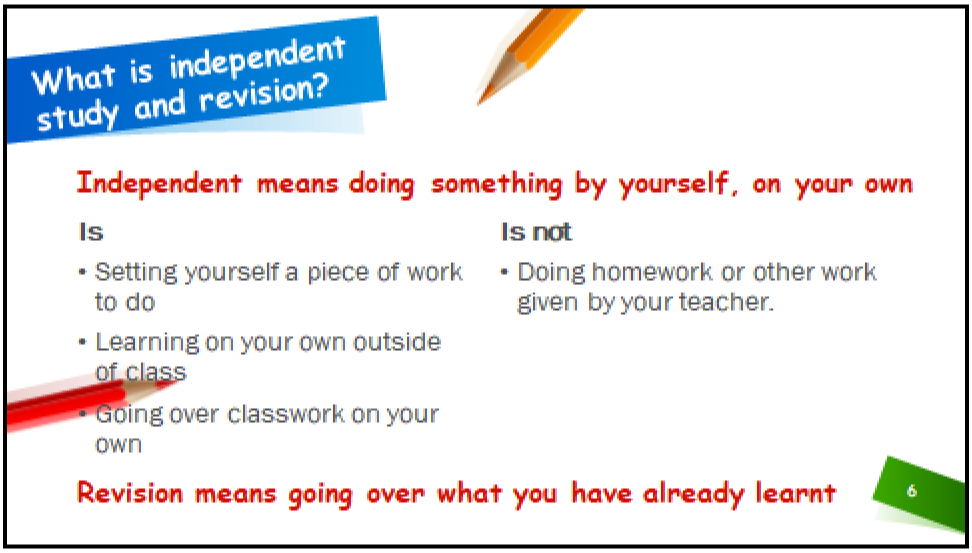
3


What will I learn about today?
What is iStER?
What is independent study and revision?
Why is it important to study and revise on my own?
What are effective ways to learn when I study and revise on my own?
4

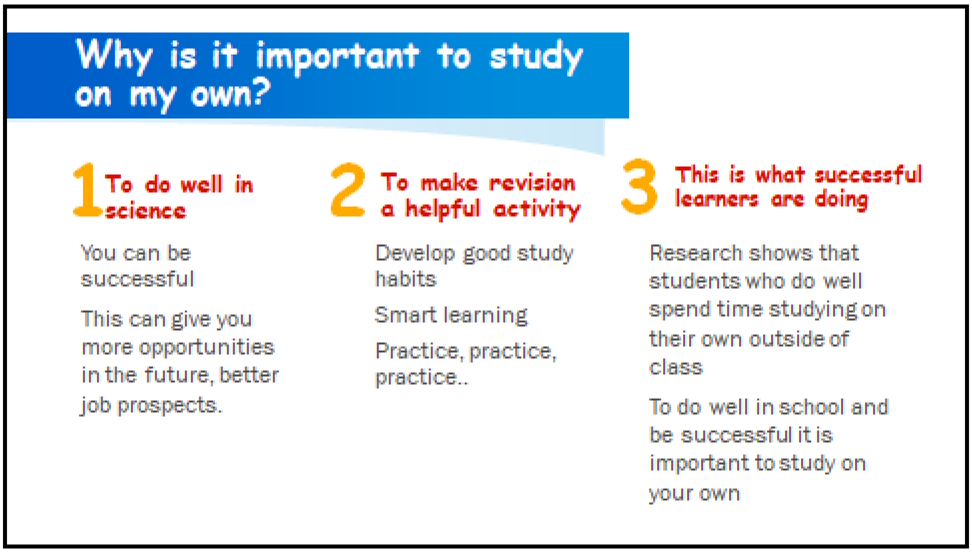
4


What is iStER?
• Improving Standards through Effective Revision
• A learning programme that teaches you about effective ways to study and revise for exams
• A learning programme that teaches you how to learn when you study and revise for exams
Research: To find out, to find out if something works or does not work
5

5


What is independent study and revision?
Independent means doing something by yourself, on your own
Is
• Setting yourself a piece of work to do
• Learning on your own outside of class
• Going over classwork on your own
Is not
• Doing homework or other work given by your teacher.
Revision means going over what you have already learnt
6

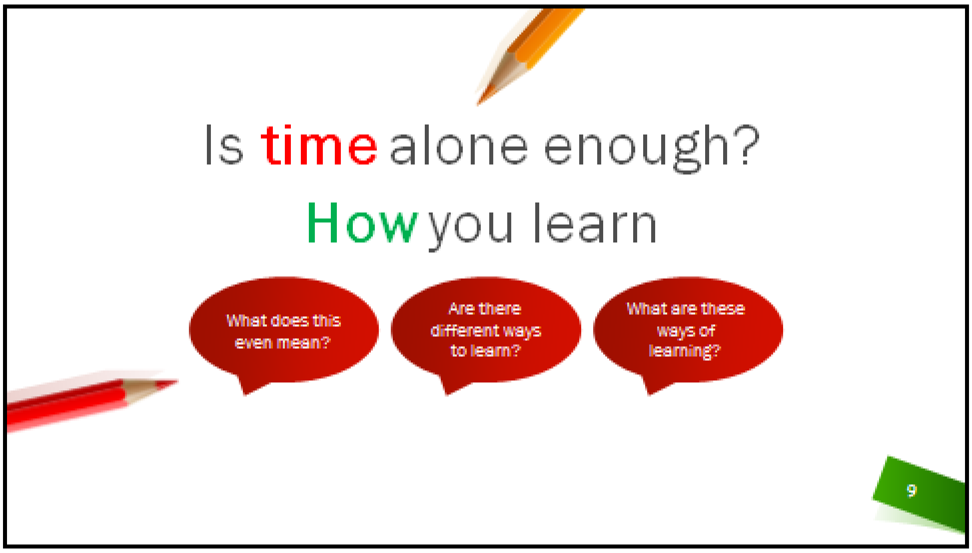
6


Why is it important to study on my own?
1 To do well in science
You can be successful
This can give you more opportunities in the future, better job prospects.
2 To make revision a helpful activity
Develop good study habits
Smart learning
Practice, practice, practice..
3 This is what successful learners are doing
Research shows that students who do well spend time studying on their own outside of class
To do well in school and be successful it is important to study on your own

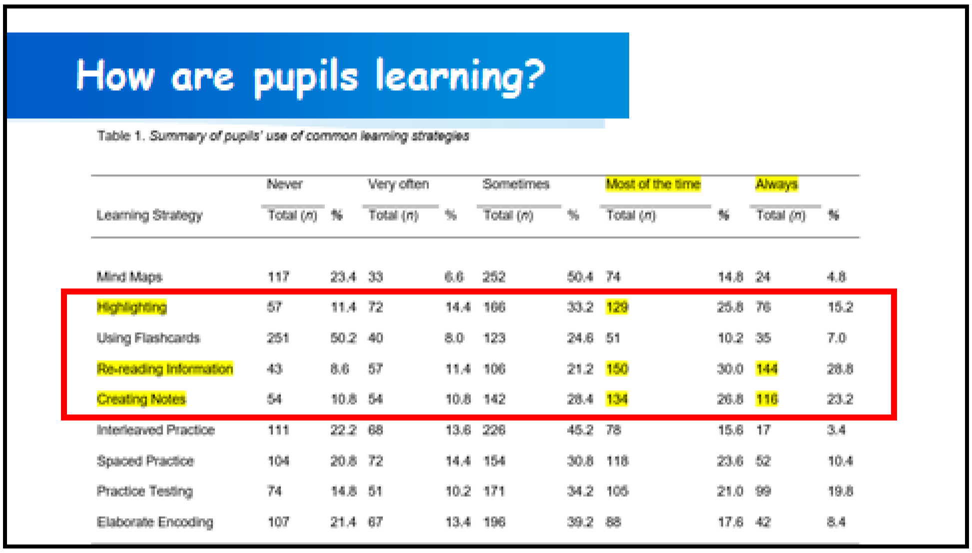
7


Think about successful people…
Tennis champions
'Special skills'
Determination and willingness to work hard
Would work hard and practice long hours
' I practiced twice as hard as anybody else. I used to just go out and practice for hours and hours and hours'.
' Willingness to work hard was one of the biggest thing that has gotten me as far as I have, I think'.
' People noticed that I worked hard. That I practiced hard'.
' They said that I worked hard'.
Who is your role model, find out how much time they spend working on what they do…

8



9



How are pupils learning?

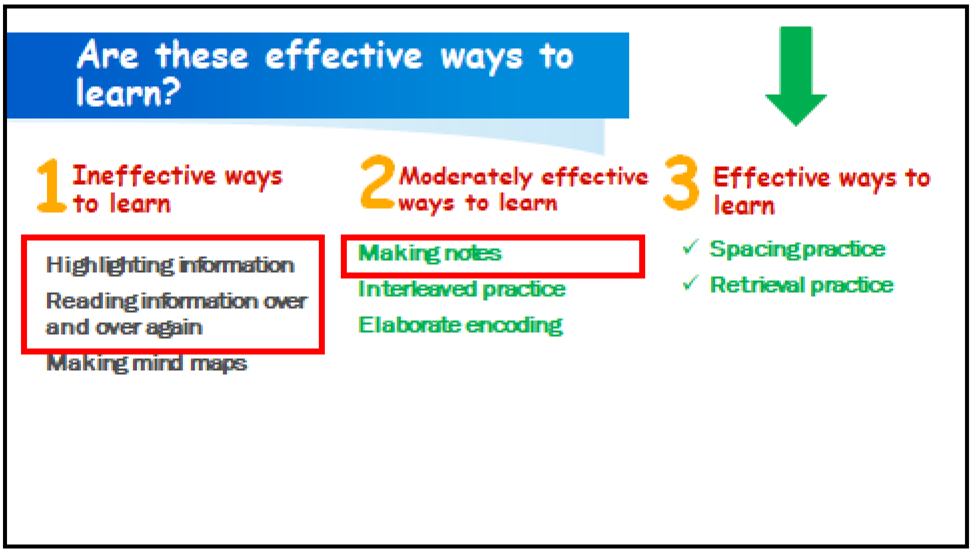
Table 1. *Summary of pupils' use of common learning strategies*

Learning Strategy	Never Total (*n*)	%	Very often Total (*n*)	%	Sometimes Total (*n*)	%	Most of the time Total (*n*)	%	Always Total (*n*)	%
Mind Maps	117	23.4	33	6.6	252	50.4	74	14.8	24	4.8
Highlighting	57	11.4	72	14.4	166	33.2	129	25.8	76	15.2
Using Flashcards	251	50.2	40	8.0	123	24.6	51	10.2	35	7.0
Re-reading Information	43	8.6	57	11.4	106	21.2	150	30.0	144	28.8
Creating Notes	54	10.8	54	10.8	142	28.4	134	26.8	116	23.2
Interleaved Practice	111	22.2	68	13.6	226	45.2	78	15.6	17	3.4
Spaced Practice	104	20.8	72	14.4	154	30.8	118	23.6	52	10.4
Practice Testing	74	14.8	51	10.2	171	34.2	105	21.0	99	19.8
Elaborate Encoding	107	21.4	67	13.4	196	39.2	88	17.6	42	8.4

10


'Familiarity trap'
Are they helpful?
Are these effective ways to learn?
11

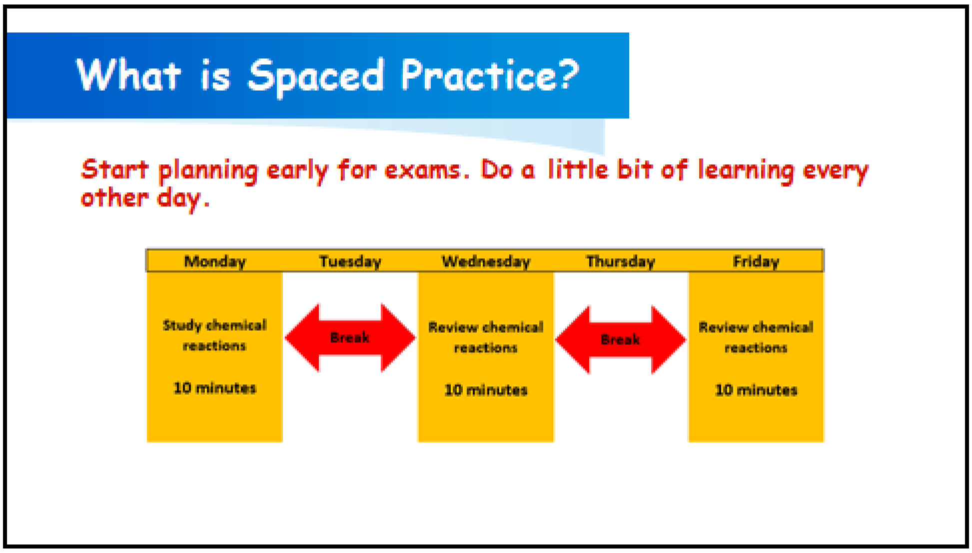
11


Are these effective ways to learn?
1 Ineffective ways to learn
Highlighting information
Reading information over and over again
Making mind maps
2 Moderately effective ways to learn
Making notes
Interleaved practice
Elaborate encoding
3 Effective ways to learn
✓ Spacing practice
✓ Retrieval practice

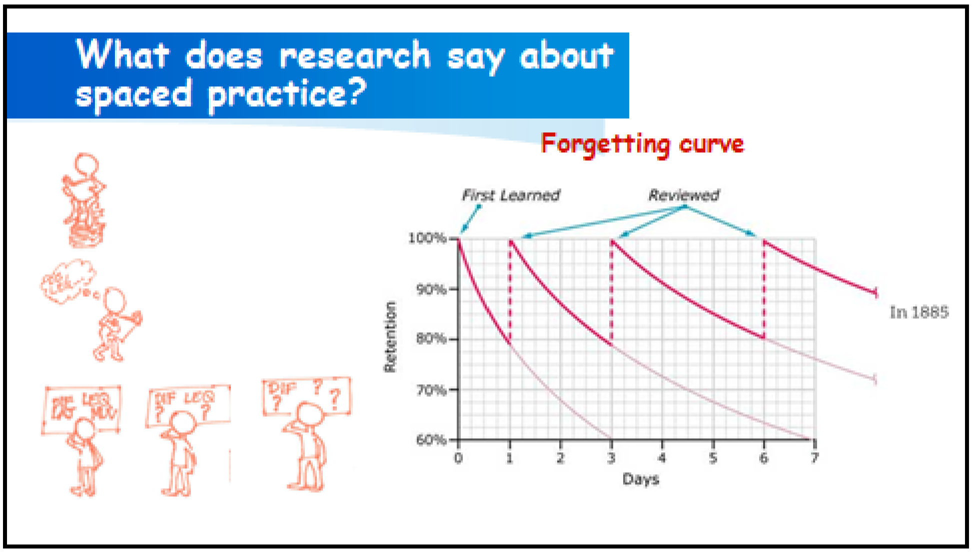
12


What are effective ways to learn?
✓ Spaced Practice
✓ Retrieval practice

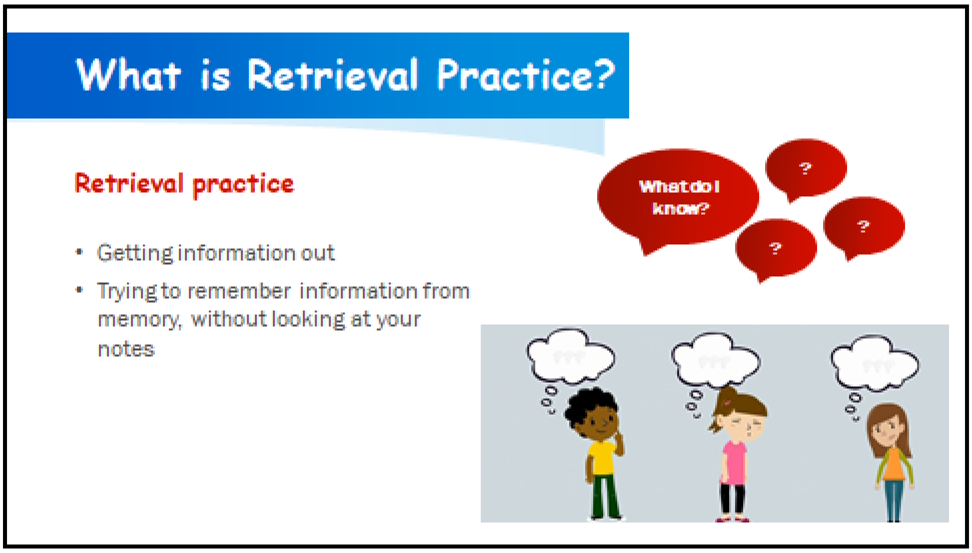
13


What is Spaced Practice?
Start planning early for exams. Do a little bit of learning every other day.
Monday
Tuesday
Wednesday
Thursday
Friday
Study chemical reactions
10 minutes
Break
Review chemical reactions
10 minutes
Break
Review chemical reactions
10 minutes

14


What does research say about spaced practice?
Forgetting curve
First Learned
Reviewed
100%
90%
80%
70%
60%
Retention
0 1 2 3 4 5 6 7
Days
In 1885

15


What is Retrieval Practice?
Retrieval practice
• Getting information out
• Trying to remember information from memory, without looking at your notes
What do I know?
?
?
?

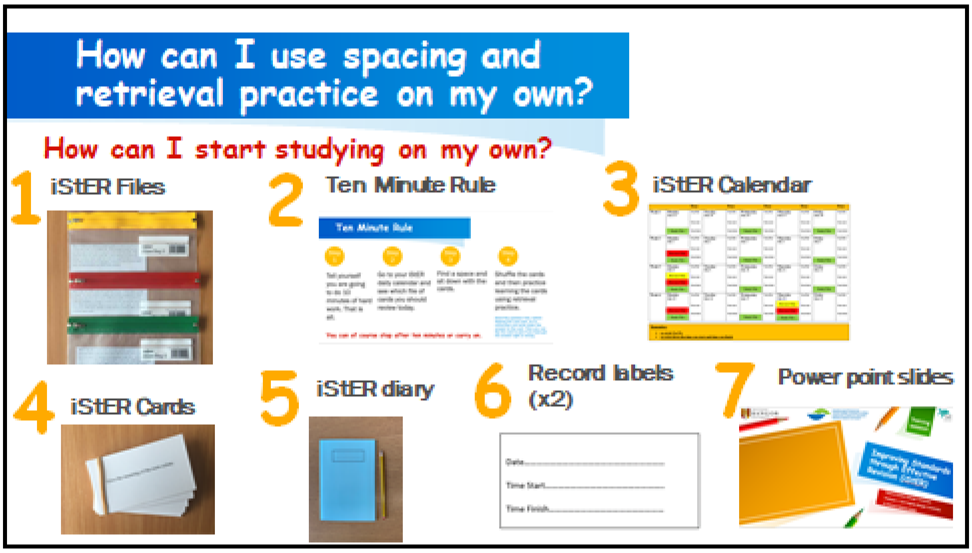
16


This sounds like doing a test!
1
2
3
TEST
Past papers
Practice tests
Quizzes
17

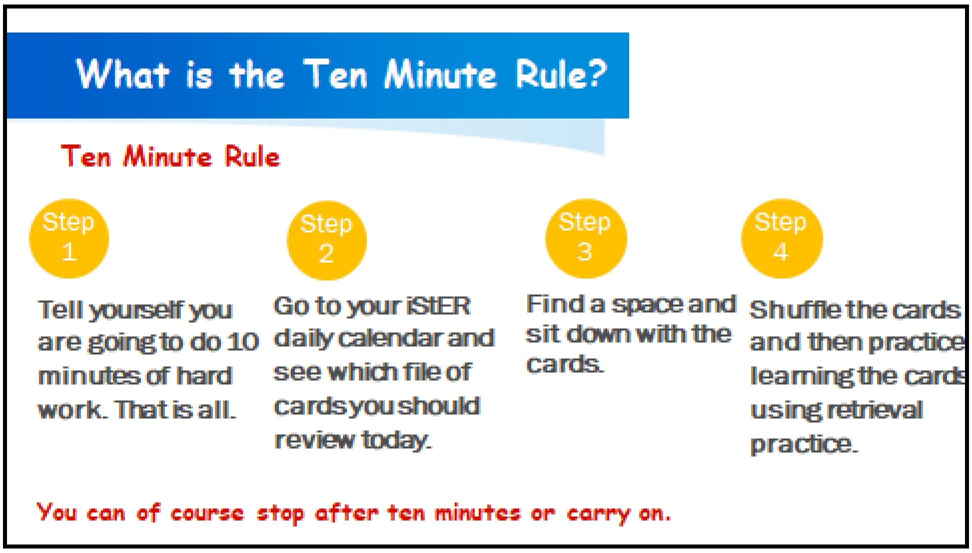
17


How can I use spacing and retrieval practice?
Improving Standards through Effective Revision (iStER)
18

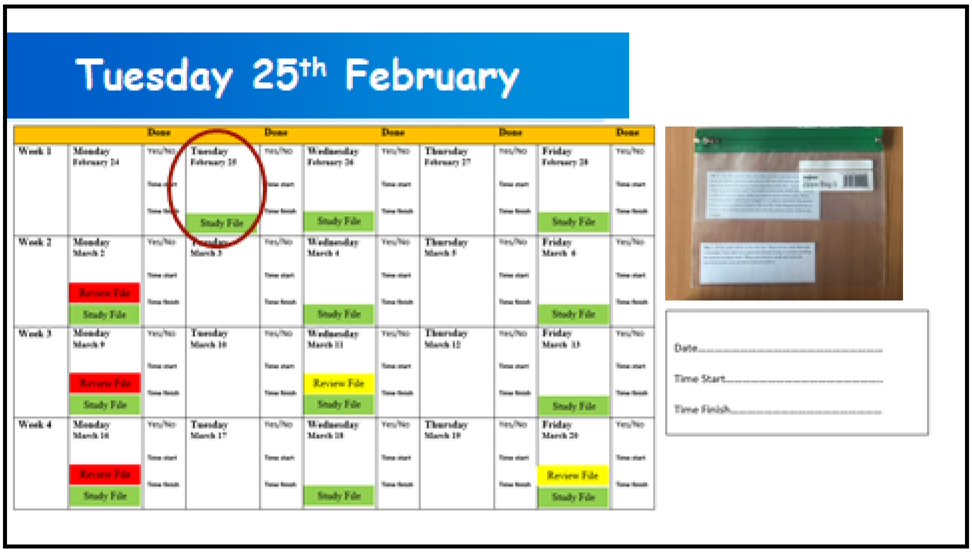
18


How can I use spacing and retrieval practice on my own?
How can I start studying on my own?
1 iStER Files
2 Ten Minute Rule
Ten Minute Rule
3 iStER Calendar
4 iStER Cards
5 iStER diary
6 Record labels (x2)
7 Power point slides

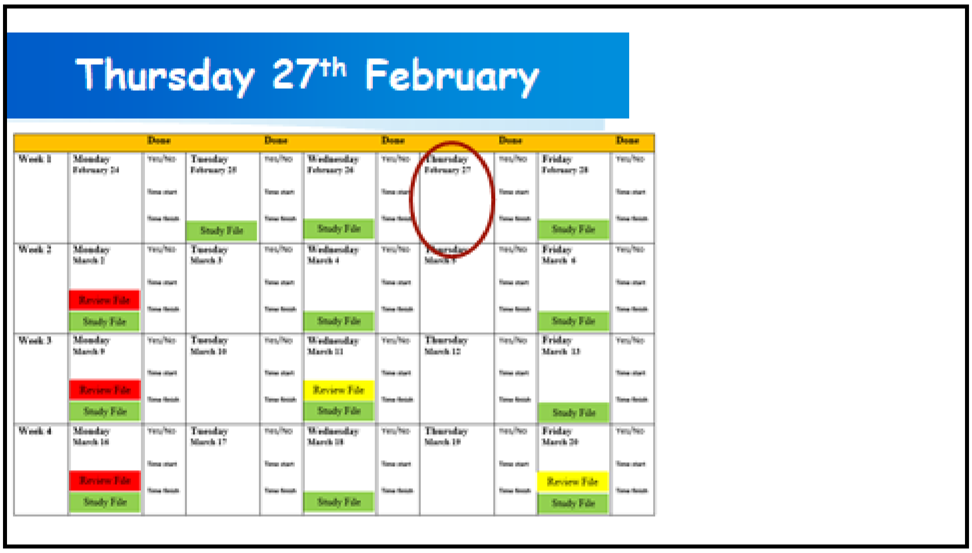
19


What is the Ten Minute Rule?
Ten Minute Rule
Step 1
Tell yourself you are going to do 10 minutes of hard work. That is all.
Step 2
Go to your iStER daily calendar and see which file of cards you should review today.
Step 3
Find a space and sit down with the cards.
Step 4
Shuffle the cards and then practice learning the cards using retrieval practice.
You can of course stop after ten minutes or carry on.

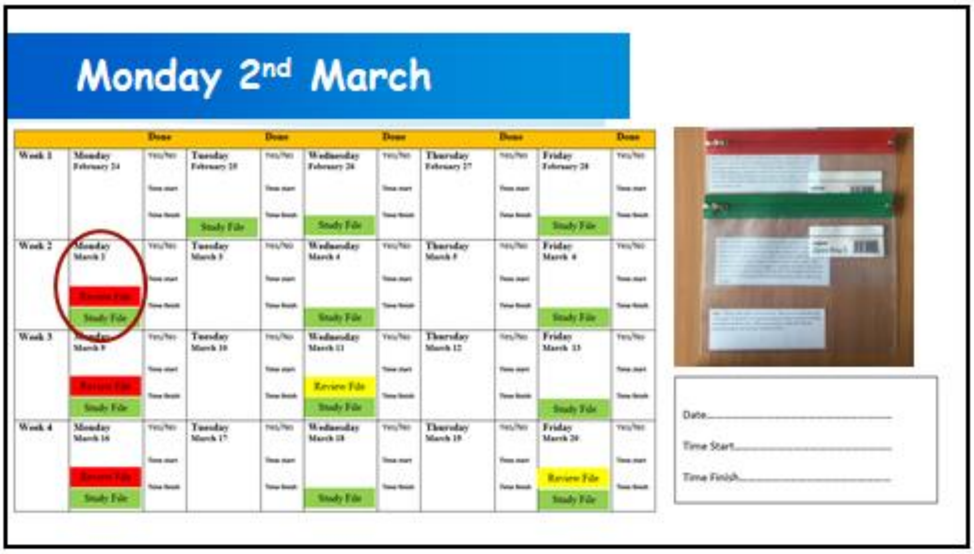
20


Tuesday 25th February
Date
Time Start
Time Finish

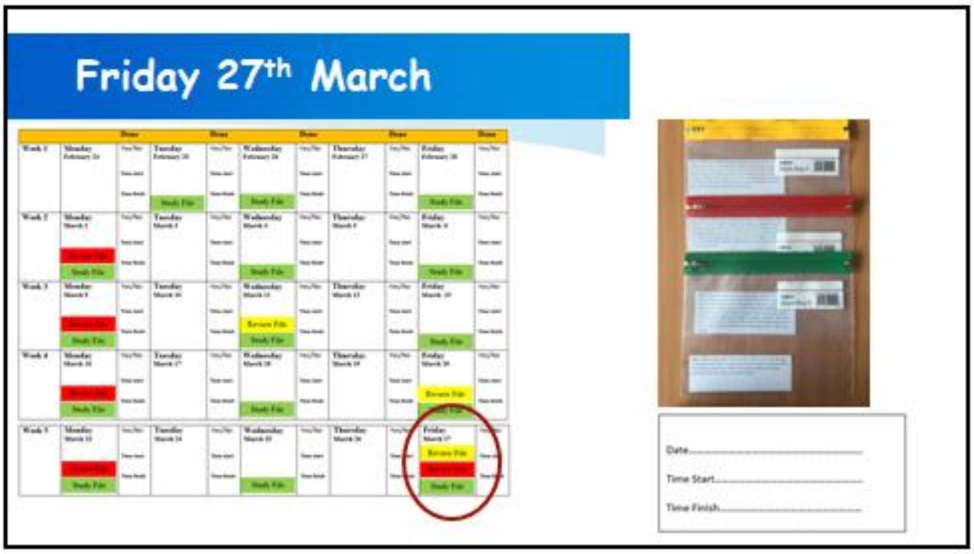
21


Thursday 27th February

22

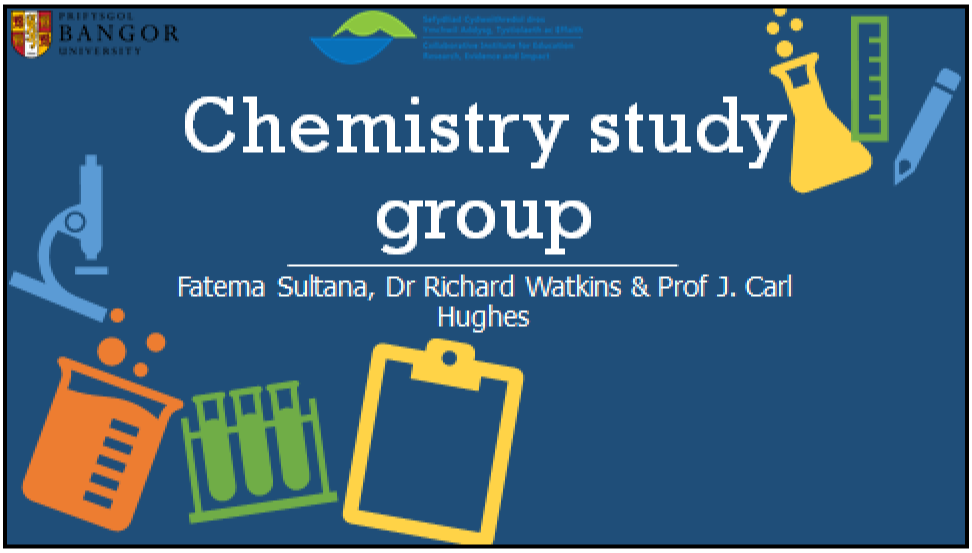

Monday 2nd March
Date
Time Start
Time Finish

23

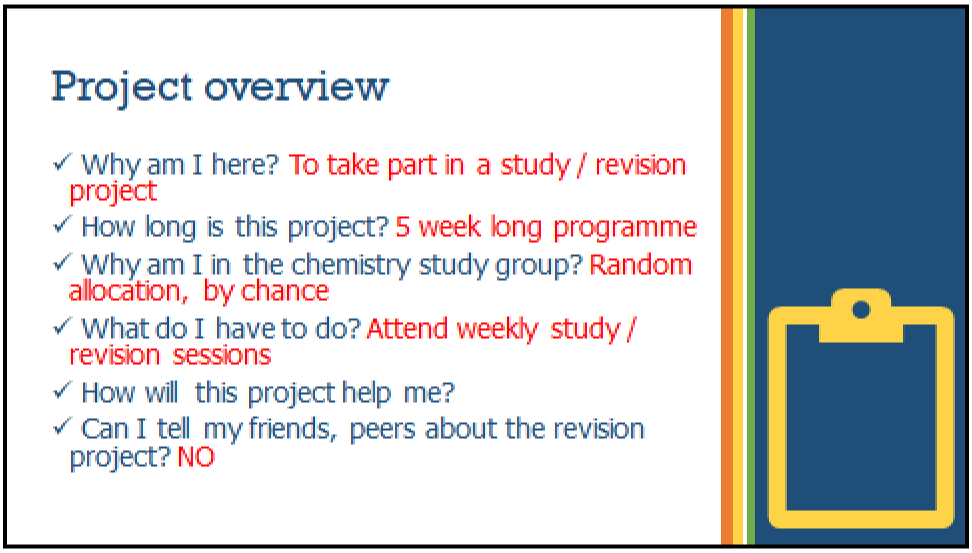

Friday 27th March
Date
Time Start
Time Finish

24

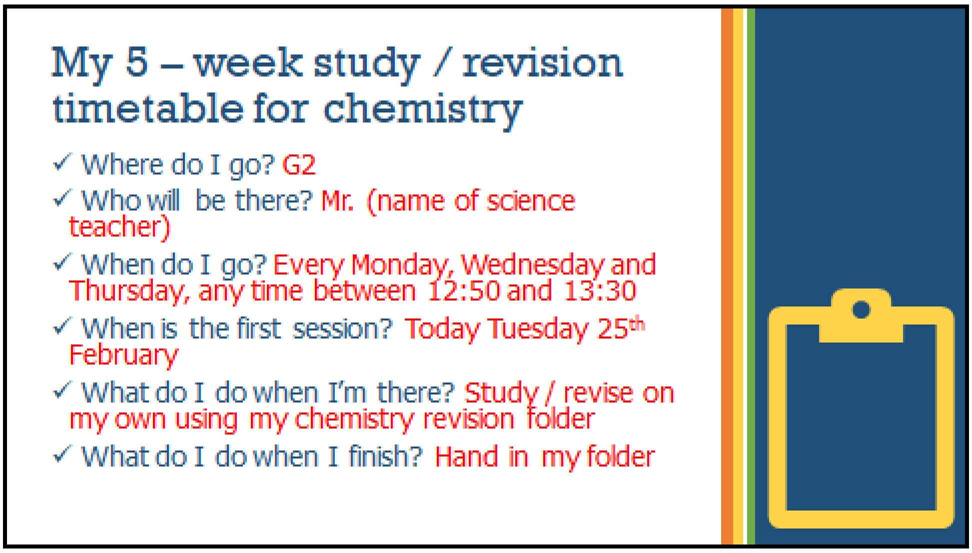
Appendix I: PowerPoint presentation slides for chemistry study group (Chapter 4)



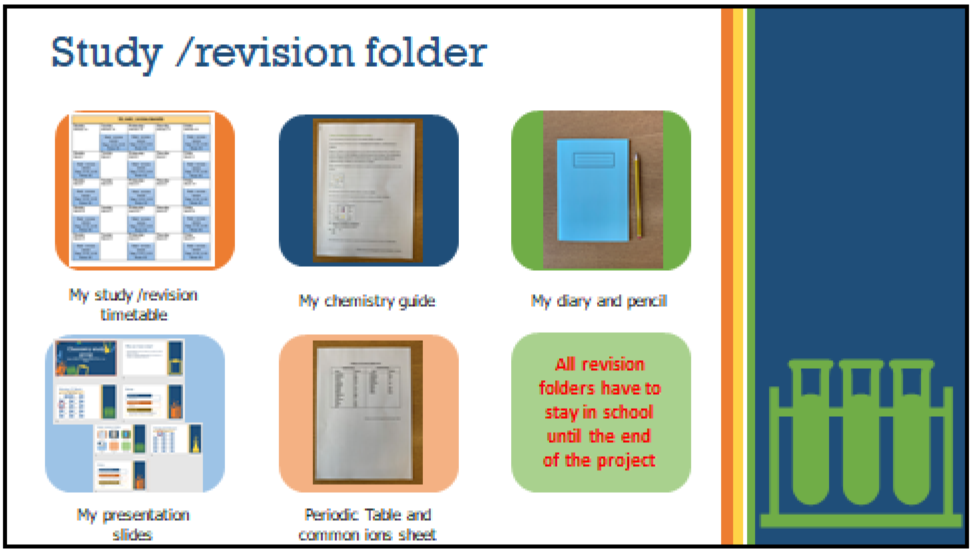
1



2


My 5 – week study / revision timetable for chemistry
✓ Where do I go? G2
✓ Who will be there? Mr. (name of science teacher)
✓ When do I go? Every Monday, Wednesday and Thursday, any time between 12:50 and 13:30
✓ When is the first session? Today Tuesday 25th February
✓ What do I do when I'm there? Study / revise on my own using my chemistry revision folder
✓ What do I do when I finish? Hand in my folder

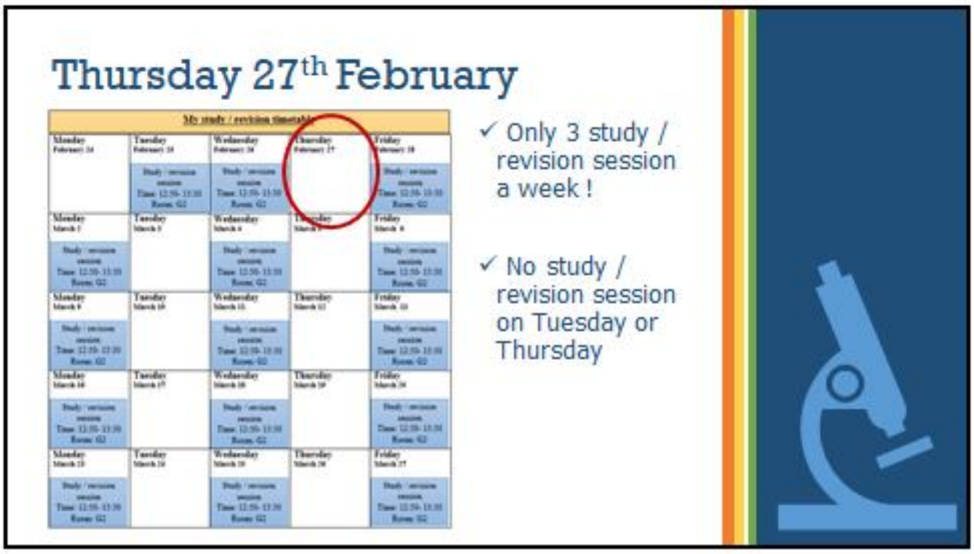
3


Study /revision folder
My study /revision timetable
My chemistry guide
My diary and pencil
My presentation slides
Periodic Table and common ions sheet
All revision folders have to stay in school until the end of the project

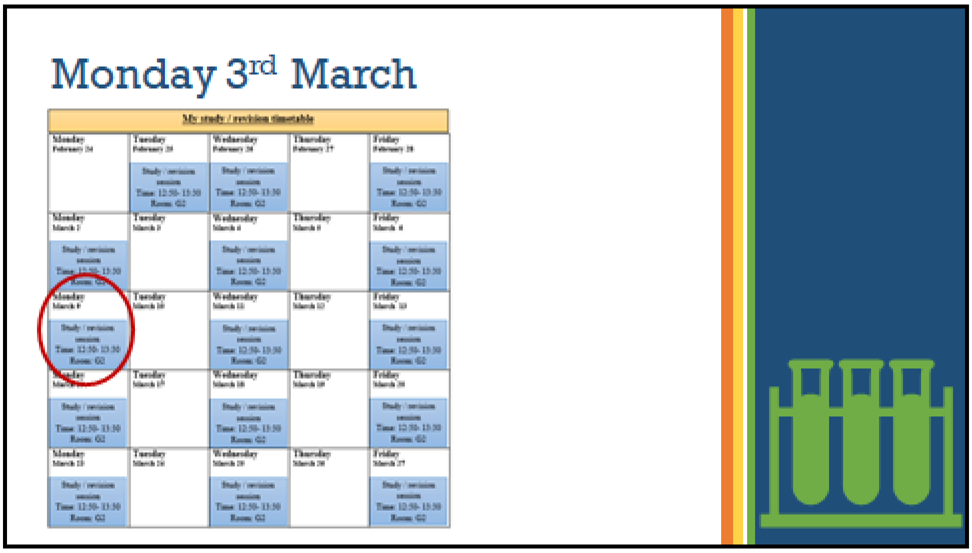
4


Tuesday 24th February
My study / revision timetable

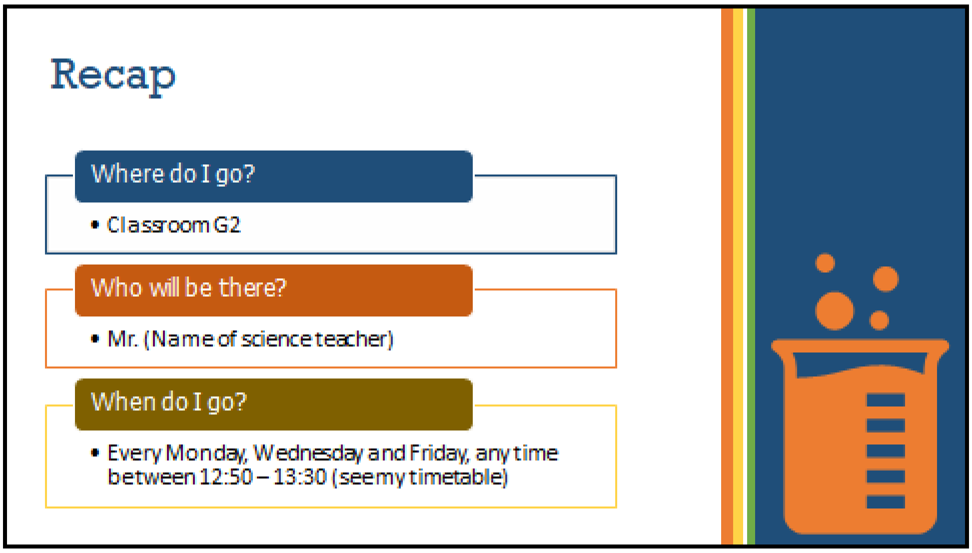
5


Thursday 27th February
My study / revision timetable
✓ Only 3 study / revision session a week !
✓ No study / revision session on Tuesday or Thursday

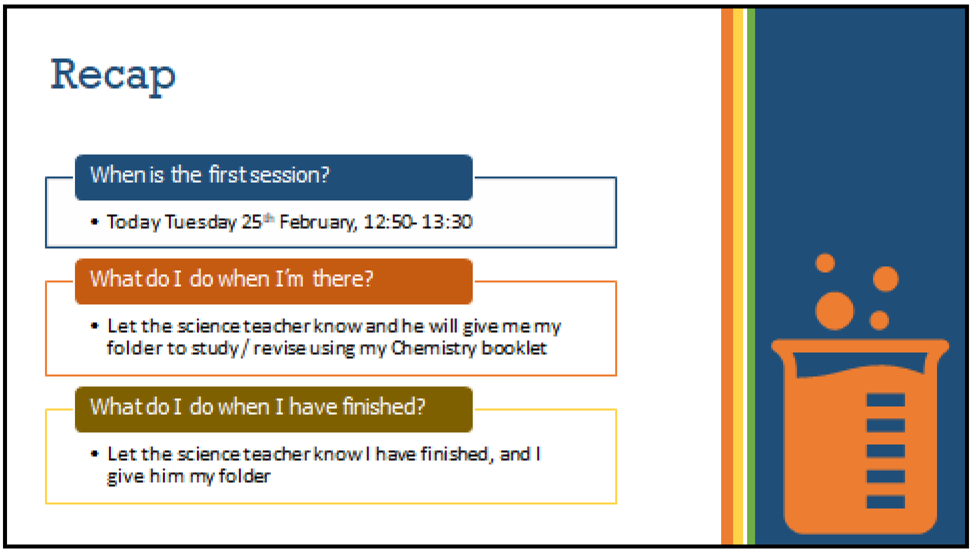
6


Monday 3rd March
My study / revision timetable

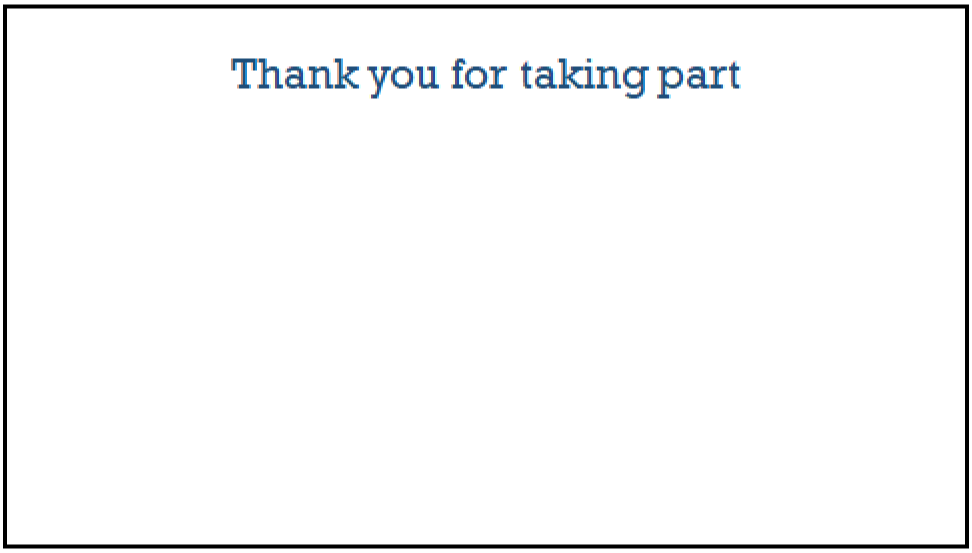
7


Recap
Where do I go?
• Classroom G2
Who will be there?
• Mr. (Name of science teacher)
When do I go?
• Every Monday, Wednesday and Friday, any time between 12:50 – 13:30 (see my timetable)

8


Recap
When is the first session?
• Today Tuesday 25th February, 12:50- 13:30
What do I do when I'm there?
• Let the science teacher know and he will give me my folder to study / revise using my Chemistry booklet
What do I do when I have finished?
• Let the science teacher know I have finished, and I give him my folder

9


Thank you for taking part

10

Appendix J: Weekly lunchtime session timetable for iSER group (Chapter 4)

My study / revision timetable

Monday	Tuesday	Wednesday	Thursday	Friday
Monday February 24	**Tuesday** February 25 Study / revision session Time: 12:50- 13:30 Room: G1	**Wednesday** February 26 Study / revision session Time: 12:50- 13:30 Room: G1	**Thursday** February 27	**Friday** February 28 Study / revision session Time: 12:50- 13:30 Room: G1
Monday March 2 Study / revision session Time: 12:50- 13:30 Room: G1	**Tuesday** March 3	**Wednesday** March 4 Study / revision session Time: 12:50- 13:30 Room: G1	**Thursday** March 5	**Friday** March 6 Study / revision session Time: 12:50- 13:30 Room: G1
Monday March 9 Study / revision session Time: 12:50- 13:30 Room: G1	**Tuesday** March 10	**Wednesday** March 11 Study / revision session Time: 12:50- 13:30 Room: G1	**Thursday** March 12	**Friday** March 13 Study / revision session Time: 12:50- 13:30 Room: G1
Monday March 16 Study / revision session Time: 12:50- 13:30 Room: G1	**Tuesday** March 17	**Wednesday** March 18 Study / revision session Time: 12:50- 13:30 Room: G1	**Thursday** March 19	**Friday** March 20 Study / revision session Time: 12:50- 13:30 Room: G1
Monday March 23 Study / revision session Time: 12:50- 13:30 Room: G1	**Tuesday** March 24	**Wednesday** March 25 Study / revision session Time: 12:50- 13:30 Room: G1	**Thursday** March 26	**Friday** March 27 Study / revision session Time: 12:50- 13:30 Room: G1

Please come to your study / revision sessions for 10 minutes at least. You can of course stay for longer if you want.

Appendix K: Weekly lunchtime session timetable for chemistry study group

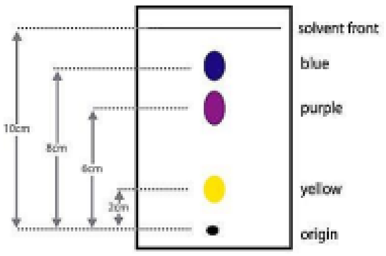
My study / revision timetable

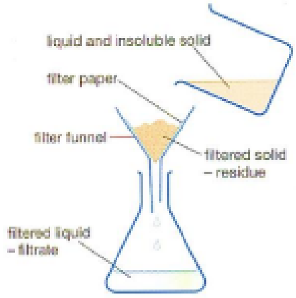
Monday	Tuesday	Wednesday	Thursday	Friday
Monday **February 24**	**Tuesday** **February 25** Study / revision session Time: 12:50- 13:30 Room: G2	**Wednesday** **February 26** Study / revision session Time: 12:50- 13:30 Room: G2	**Thursday** **February 27**	**Friday** **February 28** Study / revision session Time: 12:50- 13:30 Room: G2
Monday **March 2** Study / revision session Time: 12:50- 13:30 Room: G2	**Tuesday** **March 3**	**Wednesday** **March 4** Study / revision session Time: 12:50- 13:30 Room: G2	**Thursday** **March 5**	**Friday** **March 6** Study / revision session Time: 12:50- 13:30 Room: G2
Monday **March 9** Study / revision session Time: 12:50- 13:30 Room: G2	**Tuesday** **March 10**	**Wednesday** **March 11** Study / revision session Time: 12:50- 13:30 Room: G2	**Thursday** **March 12**	**Friday** **March 13** Study / revision session Time: 12:50- 13:30 Room: G2
Monday **March 16** Study / revision session Time: 12:50- 13:30 Room: G2	**Tuesday** **March 17**	**Wednesday** **March 18** Study / revision session Time: 12:50- 13:30 Room: G2	**Thursday** **March 19**	**Friday** **March 20** Study / revision session Time: 12:50- 13:30 Room: G2
Monday **March 23** Study / revision session Time: 12:50- 13:30 Room: G2	**Tuesday** **March 24**	**Wednesday** **March 25** Study / revision session Time: 12:50- 13:30 Room: G2	**Thursday** **March 26**	**Friday** **March 27** Study / revision session Time: 12:50- 13:30 Room: G2

Please come to your study / revision sessions for 10 minutes at least. You can of course stay for longer if you want.

Group 2

Appendix L: PDF of iStER flashcards before being sent to print unit (Chapter 4)

Give the meaning of the term solute.	Give the meaning of the term solvent.
Ethanol is soluble in water. Describe how you would separate ethanol from a ethanol-water mixture.	Draw and label the apparatus you would use to separate an insoluble solid from a water-solid mixture.
Give the term used for the soluble solid in a solution.	Give the term used for the liquid used to dissolve a solid in a solution.
Calculate the Rf value of the yellow spot on the chromatogram below 	Give the term used to describe a reaction where the temperature increases.
Give the term used to describe a reaction where the temperature decreases.	Cl_2 is an element but NaCl is a compound. Explain.

The liquid used to dissolve a solid and form a solution.	The soluble solid in a solution
	Process is called distillation. Heat the ethanol-water mixture. The ethanol has the lower boiling temperature, and therefore forms a vapour first which is then condensed using a condenser, and collected as a liquid.
Solvent	Solute
Exothermic	$Rf = \frac{\text{distance travelled by component}}{\text{distance travelled by solvent}}$ $Rf = \frac{2.0}{10.0} = 0.2$
Cl_2 is an element because it is made up of **one type of atom only** / of chlorine atoms only. NaCl is a compound because it is made up of **more than one type of atom** / made up of chlorine and sodium atoms.	Endothermic

Appendix M: Example of chemistry booklet students in chemistry study group received (Chapter 4)

Nature of substances and chemical reactions

Give the meaning of the term solute. **The soluble solid in a solution.**

Give the meaning of the term solvent. **The liquid used to dissolve a solid and form a solution.**

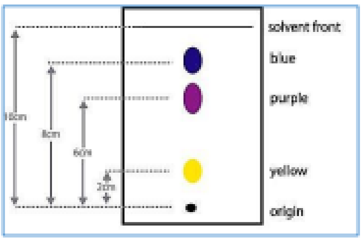
Ethanol is soluble in water. Describe how you would separate ethanol from a ethanol-water mixture. **Process is called distillation. Heat the ethanol-water mixture. The ethanol has the lower boiling temperature, and therefore forms a vapour first which is then condensed using a condenser, and collected as a liquid.**

Draw and label the apparatus you would use to separate an insoluble solid from a water-solid mixture.

Give the term used for the soluble solid in a solution. **Solute**

Give the term used for the liquid used to dissolve a solid in a solution. **Solvent**

Calculate the Rf value of the yellow spot on the chromatogram below



$$\mathbf{Rf} = \frac{\text{distance travelled by component}}{\text{distance travelled by solvent}}$$

$$\mathbf{Rf} = \frac{2.0}{10.0} = 0.2$$

Give the term used to describe a reaction where the temperature increases. **Exothermic**

Please turn over the page for more chemistry content

Appendix N: iStER Zippa File labels (Chapter 4)

File 1. All the cards will be in this file first. These are the cards that need to be learnt. Your task is to spend 10 minutes trying to practice remembering the answers on these cards. When you **correctly remember** and **write** the answer to a card, you can move it down to file two (the red file).

File 2. This file contains the cards that you have just moved out of file one (the green file); these are freshly learned cards and so can still **confuse** you. Your task is to spend 10 minutes reviewing these cards. You need to look at the iStER daily calendar as this will let you know when you need to review the cards in this file. When reviewing these cards if you **struggle** to or **cannot remember** the answer then you have to move it back to file one (green file). If you **can** remember and write the answer to a card **easily without any struggle** then you can move the card down to file three (the yellow file).

File 3. This file will contain the cards that you get correct when you test yourself. You **feel confident** remembering and writing the answers to these cards, even when the information is difficult. If you make any **mistakes** or **struggle** to remember the answer at all, the card must be moved into file two (the red file).
You need to look at the iStER daily calendar as this will let you know when you need to review the cards in this file.

Appendix O: iStER calendar contained in the iStER resource packs (Chapter 4)

		Done		Done		Done		Done		Done
Week 1	**Monday** **February 24**	Yes/No Time start Time finish	**Tuesday** **February 25** Study File	Yes/No Time start Time finish	**Wednesday** **February 26** Study File	Yes/No Time start Time finish	**Thursday** **February 27**	Yes/No Time start Time finish	**Friday** **February 28** Study File	Yes/No Time start Time finish
Week 2	**Monday** **March 2** Review File Study File	Yes/No Time start Time finish	**Tuesday** **March 3**	Yes/No Time start Time finish	**Wednesday** **March 4** Study File	Yes/No Time start Time finish	**Thursday** **March 5**	Yes/No Time start Time finish	**Friday** **March 6** Study File	Yes/No Time start Time finish
Week 3	**Monday** **March 9** Review File Study File	Yes/No Time start Time finish	**Tuesday** **March 10**	Yes/No Time start Time finish	**Wednesday** **March 11** Review File Study File	Yes/No Time start Time finish	**Thursday** **March 12**	Yes/No Time start Time finish	**Friday** **March 13** Study File	Yes/No Time start Time finish
Week 4	**Monday** **March 16** Review File Study File	Yes/No Time start Time finish	**Tuesday** **March 17**	Yes/No Time start Time finish	**Wednesday** **March 18** Study File	Yes/No Time start Time finish	**Thursday** **March 19**	Yes/No Time start Time finish	**Friday** **March 20** Review File Study File	Yes/No Time start Time finish
Week 5	**Monday** **March 23** Review File Study File	Yes/No Time start Time finish	**Tuesday** **March 24**	Yes/No Time start Time finish	**Wednesday** **March 25** Study File	Yes/No Time start Time finish	**Thursday** **March 26**	Yes/No Time start Time finish	**Friday** **March 27** Review File Review File Study File	Yes/No Time start Time finish

Remember:

- **to circle Yes/No**
- **to write down the time you start and time you finish**
- **Follow the order of the colours**

Appendix P: Frequency outcome scores for journal entries made by the iStER intervention and chemistry study group students (Chapter 4)

Table P. 1 *Frequency scores for journal entries completed by iStER intervention group students during weekly lunchtime sessions.*

	Session								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Student 32	5	5	7	6	7	6	5	13	7
Student 30	14	19	29		14	9	14	8	
Student 28	6				5	6	9	18	9
Student 29	9	13	11		10		15		11
Student 33	5		7			5	7		7
Student 25		9	9	8			7		9
Student 24				3		7			

Table P. 2 *Frequency scores for journal entries completed by chemistry study intervention group students during the weekly lunchtime sessions.*

	Session								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Student 22	4	10	11	8	11		5	7	7
Student 12	5	4	2	3		2			1
Student 18[a]	0				4	3	4	2	3
Student 19	4		3		6		7	6	

	Session								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Student 21	7		5		1		5	9	
Student 14		1						6	5
Student 13[b]	0	0							
Student 17						5			

Note. We have presented the data only for the students who attended the sessions. The gaps show any session(s) students missed. [ab]In the first session student 18 was present and in the first and second sessions student 13 was present, however, no journal entries were made by these students for those sessions. However, because the students were present for those sessions, we have presented their data alongside and have used a zero to indicate no journal entries were made during those sessions for these students.

Appendix Q. Changes made to the ERaSSQ survey for the CEN study (Appendix E)

Table Q. 1 *Overview of modifications to the ERaSSQ survey*

Survey item used in earlier version of ERaSSQ	**Survey item used in present version of ERaSSQ for study**	**Description**
N/A	Since the start of the COVID-19 pandemic until the present day, how often did you use the following learning resources to learn schoolwork, study and/or revise at home? Please tick the box. **Response options:** *Never, rarely, sometimes, most of the time, always*	This was a new survey item added to measure learners use of study resources. The survey item reflects the change in the delivery of schoolwork as learners were required to undertake independent work during the pandemic.
How often do you use the following learning strategies when you study/revise for science? Please tick the box that best describes your answer. **List of learning strategies:** *Using mind maps* *Highlighting or underlining information/text* *Using flashcards* *Reading information/notes over and over* *Making notes (summarising)* *Spaced practice (spreading study/revision*	Since the start of the COVID-19 pandemic until the present day, for any of the learning resources listed below have you used and/or made your own **mind maps** whilst accessing any of these learning resources for schoolwork, study and/revision at home? Please tick all boxes that apply. The same survey item was repeated nine times and used for each of the nine learning strategies assessed in the present study;	This survey item was modified for the present study. The initial version was designed to measure which learning strategies learners use for independent work. For the current study, we modified this survey item to measure which learning strategies learners were using whilst accessing the various study resources for independent work. Minor modifications were also made to the learning strategy terms as well as

Survey item used in earlier version of ERaSSQ	**Survey item used in present version of ERaSSQ for study**	**Description**
sessions over time) *Doing practice tests (e.g., past papers)* *Interleaved practice (mixing different science subjects or science topics while studying/revising)* *Elaborate encoding (connecting what you are trying to learn to what you already know e.g., remembering the colours on the visible spectrum by learning he following sentence; Richard Of York Gave Battle in Vain [Red Orange, Yellow, Green, Blue, Indigo, Violet])* **Likert scale options:** *Never, rarely, sometimes, most of the time, always*	*Using mind maps* ***Modified:** Highlighting and/or underlining information/text* *Using flashcards* *Reading information/notes over and over* ***Modified:** Making notes and/or summarising information* ***Modified:** Spaced practice (Spaced practice involves spreading your study time and going over the same information)* ***Modified:** Retrieval practice (Retrieval practice includes answering past paper questions, quizzes, being tested by someone else or any other activity which involves remembering information from memory without looking at the information that you are trying to remember)* ***Modified:** Interleaved practice (i.e., organising your study time so that you mix different kinds of problems or topics within a single study session)* *Elaborate encoding (involves connecting what you are trying to learn to what you already know e.g. remembering the colours on the visible spectrum by learning the*	the definitions of the learning strategies included in survey items. These are highlighted as being modified.

Survey item used in earlier version of ERaSSQ	**Survey item used in present version of ERaSSQ for study**	**Description**
	following sentence; Richard Of York Gave Battle in Vain [Red, Orange, Yellow, Green, Blue, Indigo and Violet]). These are called mnemonics.	
There are two parts to this question. For the first part, using the list of learning strategies above, please write down on the dotted line below, the THREE learning strategies that YOU most frequently use when you study/revise for science. For the second part, please tick the boxes to show how well YOU think the THREE strategies that YOU have written down help you learn when you study/revise for science. **List of learning strategies:** *Using mind maps* *Highlighting or underlining information/text* *Using flashcards* *Reading information/notes over and over* *Making notes (summarising)* *Spaced practice (spreading study/revision*	How effective (i.e., helpful) do you think the following learning strategies are for schoolwork, study and/or revision. Please tick the box that best describes your answer. **List of learning strategies:** *Using mind maps* ***Modified:** Highlighting and/or underlining information/text* *Using flashcards* *Reading information/notes over and over* ***Modified:** Making notes and/or summarising information* ***Modified:** Spaced practice (Spaced practice involves spreading your study time and going over the same information)* ***Modified:** Retrieval practice (Retrieval practice includes answering past paper*	In the current study we asked learners to rate the effectiveness of **all** the listed learning strategies. Learners could also select the ‘I am not sure option. In contrast, in the initial version of the ERaSSQ survey, we asked learners to first list three strategies they most frequently use and only evaluate those strategies on their helpfulness. Following peer review in an academic journal this survey item was modified to measure learners' understanding of the effectiveness of **all** learning strategies, to create an overview of what learners understand to be the most and least effective strategies. Was modified due to the restricted nature of the question format and to create an overview of how students assess the effectiveness of all nine

Survey item used in earlier version of ERaSSQ	**Survey item used in present version of ERaSSQ for study**	**Description**
sessions over time) *Doing practice tests (e.g., past papers)* *Interleaved practice (mixing different science subjects or science topics while studying/revising)* *Elaborate encoding (connecting what you are trying to learn to what you already know e.g., remembering the colours on the visible spectrum by learning he following sentence; Richard Of York Gave Battle in Vain [Red Orange, Yellow, Green, Blue, Indigo, Violet])* **Likert scale options:** *Not at all helpful, slightly helpful, moderately helpful, very helpful, extremely helpful*	*questions, quizzes, being tested by someone else or any other activity which involves remembering information from memory without looking at the information that you are trying to remember)* ***New strategy:*** *Watching videos on the subject topic* ***New strategy:*** *Listening to audio on the subject topic* ***Modified:*** *Interleaved practice (i.e., organising your study time so that you mix different kinds of problems or topics within a single study session)* *Elaborate encoding (involves connecting what you are trying to learn to what you already know e.g. remembering the colours on the visible spectrum by learning the following sentence; Richard Of York Gave Battle in Vain [Red, Orange, Yellow, Green, Blue, Indigo and Violet]). These are called mnemonics.* **Likert scale options:** *Not at all helpful, slightly helpful, moderately helpful, very helpful, extremely helpful, I am*	(or perhaps even more) strategies. Two additional strategies identified from the findings to the open-response questions in our earlier survey were included (*watching videos on the subject topic, listening to audio on the subject topic*).

Survey item used in earlier version of ERaSSQ	**Survey item used in present version of ERaSSQ for study**	**Description**
	not sure	
N/A	How effective (i.e., helpful) do you think the following learning resources are for schoolwork, study and/or revision. Please tick the box that best describes your answer. **List of learning resources:** BBC bitesize, Quizlet, Tanio.Cymru, Hwb Platform, WJEC website, AQA website, Khan Academy, Oak National Academy, Seneca Learning, Text book/guide, Information/notes uploaded by your teacher(s) on your school's digital learning platform or other online platforms such as Google Classroom and Microsoft Teams, Information/notes in my class book and/or folder **Likert scale options:** *Not at all helpful, slightly helpful, moderately helpful, very helpful, extremely helpful, I am not sure*	This was a new survey item added to measure learners' understanding of the effectiveness of study resources. The survey item reflects the change in the delivery of schoolwork as learners were required to undertake independent work during the pandemic.

Survey item used in earlier version of ERaSSQ	Survey item used in present version of ERaSSQ for study	Description
N/A	During the COVID-19 pandemic think about a week when you were learning at home all the time and did not go to school. For that week, how many hours of schoolwork did you do at home. Please tick ONE box. *Schoolwork is any work that your teacher asked you to do and given to you by your teacher(s) (i.e., classwork, online classroom lessons with your teacher(s)).* **Response options:** *None, less than 1 hour a week, 1-2 hours a week, 2-3 hours a week, 3-4 hours a week, 4-5 hours a week, 5-6 hours a week, 6-7 hours a week, more than 7 hours a week*	This was a new survey item added to measure the time learners spent on schoolwork during the COVID-19 school closures. The survey item reflects the change in the delivery of schoolwork as learners were required to undertake independent work during the pandemic.
In a typical week how many minutes/hours of study do you do for science outside of lessons? Please tick the box. **Response options:** *Less than 1 hour study a week, 1-2 hours study a week, 2-3 hours study a week, 3-4 hours study a week, 4-5 hours study a week, 5-6 hours study a week, 6-7 hours study a*	During the COVID-19 pandemic think about a week when you were learning at home. How many hours of independent study did you do at home when your school was closed. Please tick ONE box. *Independent study can be spending some time going over the schoolwork that you have learned by yourself, or any additional work that you set yourself to do.*	This survey item was modified for the present study, including changes to the wording of the survey question and response options.

Survey item used in earlier version of ERaSSQ	**Survey item used in present version of ERaSSQ for study**	**Description**
week, more than 7 hours study a week	**Response options:** *None (**new option**), less than 1 hour a week, 1-2 hours a week, 2-3 hours a week, 3-4 hours a week, 4-5 hours a week, 5-6 hours a week, 6-7 hours a week, more than 7 hours a week*	
N/A	At the **start of the COVID-19 school closures** when you started home learning, how confident did you feel about using the following digital learning platforms? Please tick the box that best describes your answer. How confident do you **NOW** feel about using the following digital learning platforms. Please tick the box that best describes your answer. **List of digital learning platforms:** *Hwb Platform, Microsoft Teams, Google classroom, Moodle, Show my homework* **Response options:**	These were two new survey items added to measure learners' confidence in using digital learning platforms at the start of COVID-19 school closures and at the present time of completing the ERaSSQ the survey (April-May 2022). The survey item reflects the change in the delivery of schoolwork as learners were required to undertake independent work during the pandemic.

Survey item used in earlier version of ERaSSQ	**Survey item used in present version of ERaSSQ for study**	**Description**
	Not confident at all, slightly confident, somewhat confident, very confident, extremely confident, our school did not use this / We did not use this	
N/A	At the **start of the COVID-19 school closures**, how confident did you feel about each of the following aspects of learning? Please tick the box that best describes your answer. How confident do you **NOW** feel about each of the following aspects of learning? Please tick the box that best describes your answer. **List of study activities:** *Learning schoolwork on my own outside of school without help from school teacher(s)* *Using online learning resources* *Using the internet for finding effective (i.e., helpful) learning resources* *Using effective (i.e., evidence- informed) learning strategies* *Using the internet for*	These were two new survey items added to measure learners' confidence in using digital learning platforms at the start of COVID-19 school closures and at the present time of completing the ERaSSQ the survey (April-May 2022).

Survey item used in earlier version of ERaSSQ	**Survey item used in present version of ERaSSQ for study**	**Description**
	finding effective (i.e., helpful) learning strategies *Using offline learning resources (e.g., textbooks, study/revision guides)* *Studying on my own outside of school (i.e., doing work other than homework)* *Revising on my own in preparation for class tests, external exams at home* **Response options:** *Not confident at all, slightly confident, somewhat confident, very confident, extremely confident, our school did not use this / We did not use this*	
N/A	If you know about any of these **learning strategies**, please tell us where you found out about them? Please tick all boxes We used the same abovementioned list of learning strategies. If you know about any of	These were two new survey items added to measure where learners' knowledge of learning strategies and study resources came from. Following peer review in an academic journal this survey item was added to measure where learners' knowledge about learning

Survey item used in earlier version of ERaSSQ	**Survey item used in present version of ERaSSQ for study**	**Description**
	these online/offline **learning resources**, please tell us where you found out about them? Please tick all boxes that apply. We used the same above mentioned list of learning resources.	strategies and resources came from. To gain a better understanding of learners independent study practice.
Imagine that you are planning to study and/or revise for an upcoming science test. Please tick the option that best describes your answer, for why you might use do practice tests (e.g., past papers) to study/revise in preparation for the test. **Response options:** *Doing practice tests when I study/revise will help me to know how well I have learned the information for the science tests.* *Doing practice tests when I study/revise will help me to learn and remember the information for the science test.* *I do not think doing practice tests when I study/revise will help me learn and remember the information for the science test.*	Imagine that you are planning to study and/or revise for some information that you have learned in school. Please tick the option that best describes why you might use **retrieval practice** to study/revise the information that you have learned in school. ***Retrieval practice*** *includes answering past paper questions, quizzes, being tested by someone else or any other activity which involves remembering information from memory without looking at the information that you are trying to remember.* Please only tick **ONE** option **Response options:** *Using retrieval practice when I study/revise will help me to know how well I have learned the*	This survey item was modified for the present study, including changes to the wording of the survey question, the term used for the learning strategy in the survey question and response options.

Survey item used in earlier version of ERaSSQ	**Survey item used in present version of ERaSSQ for study**	**Description**
We used the same above question style to measure learners' understanding of the learning strategies spaced practice, using mind minds and using flashcards.	*information.* *Using retrieval practice when I study/revise will help me to learn and remember the information.* *I do not think using retrieval practice when I study/revise will help me learn and remember the information.* We used the same above mentioned question style to measure learners' understanding of the learning strategies spaced practice, using mind minds and using flashcards.	
N/A	Which of the following strategies do you think research has found to be better for long-term retention of material (i.e., for remembering information), assuming the total amount of study is the same? Please only tick ONE option. **Response options:** *Studying the material in multiple session of shorter duration* *Studying the material in one longer session* *Both strategies are*	This was a new survey item added to measure learners' understanding of the learning strategy spaced practice in a different way. Findings from our earlier survey showed learners understand the benefits of spaced practice, however, reported using this effective strategy less frequently compared with other less effective strategies. It was therefore important to assess learners' understanding of spacing practice using a different

Survey item used in earlier version of ERaSSQ	**Survey item used in present version of ERaSSQ for study**	**Description**
	equally effective (i.e., helpful)	question.
N/A	During the COVID-19 school closures, how helpful was the support you received from your school for the following aspects of home learning. Please tick the box that best describes your answer **Aspects of home learning:** *Using your school's digital learning platform* *Using other online platforms such as Google Classroom, Microsoft Teams to access schoolwork and/or communicate with your school teacher(s)* **Response options:** *Not at all helpful, somewhat helpful, moderately helpful, very helpful, extremely helpful*	New survey item related to the COVID-19 pandemic.
Do you think that you should be provided with information about effective learning strategies to help study/revise for science? Please tick the box.	Do you think that you should be provided with information about effective learning strategies and/or learning resources to help you with schoolwork, study/revision in the event of any future	This survey item was modified for the present study, including minor changes to the wording of the survey question that related to the COVID-19 pandemic.

Survey item used in earlier version of ERaSSQ	**Survey item used in present version of ERaSSQ for study**	**Description**
Response options: *Yes* *No*	school closures? Please tick the box. **Response options:** *Yes* *No*	
Would you be interested in receiving information about evidence-based learning strategies that will help you to study/revise effectively for science? Please tick the box. **Response options:** *Yes* *No*	Would you be interested in receiving information about effective (i.e., evidence-informed) learning strategies and/or learning resources that will help you to learn schoolwork, study/revise effectively? Please tick the box. **Response options:** *Yes* *No*	This survey item was modified for the present study, including minor changes to the wording of the survey question that related to the COVID-19 pandemic.

Appendix R. Modified version of Effective Revision and Study Strategies Questionnaire (ERaSSQ) (Appendix E)

Page 2: Effective Revision and Study Strategies Questionnaire

Survey Instructions

- Please tick the appropriate box or fill in the answer
- There is no right or wrong answer
- Please choose the answer which represents your view
- Your answers will not reflect on your current performance in school or that of your school

Section 1: Use of Learning Resources and Learning Strategies

This section of the survey asks you about the learning resources and learning strategies that you used for schoolwork, study and/or revision since the start of the coronavirus (COVID-19) pandemic until the present day, whilst at home.

Your answers will help us to understand how we can help learners to study and/or revise more effectively.

2. Since the start of the COVID-19 pandemic until the present day, how often did you use the following learning resources to learn schoolwork, study and/or revise at home? Please tick the box.

	Never	Rarely	Sometimes	Most of the time	Always
BBC Bitesize	☐	☐	☐	☐	☐
Quizlet	☐	☐	☐	☐	☐
Tanio Cymru	☐	☐	☐	☐	☐
Hwb Platform	☐	☐	☐	☐	☐
WJEC website	☐	☐	☐	☐	☐
AQA website	☐	☐	☐	☐	☐
Khan Academy	☐	☐	☐	☐	☐
Oak National Academy	☐	☐	☐	☐	☐
Seneca Learning	☐	☐	☐	☐	☐
Text book/guide	☐	☐	☐	☐	☐
Information/notes uploaded by your teacher(s) on your school's digital learning platform or other online platforms such as Google Classroom and Microsoft Teams	☐	☐	☐	☐	☐
Information/notes in my class book/folder	☐	☐	☐	☐	☐

2.a. Since the start of the COVID-19 pandemic until the present day, if you used a different learning resource(s) for school work, study and/or revision at home, that is not mentioned above, please write this resource(s) in the space below.

The following questions are about the learning strategies that you might have used whilst using the learning resources mentioned above (i.e., *how* you learned information).

Learning strategies are the methods (i.e., *different ways*) that you use to learn information for schoolwork, study and/or revision.

3. Since the start of the COVID-19 pandemic until the present day, for any of the learning resources listed below have you used and/or made your own **mind maps** whilst accessing any of these learning resources for schoolwork, study and/revision at home? Please tick all boxes that apply.

☐ BBC Bitesize

- Quizlet
- Tapio Cymru
- WJEC website
- AQA website
- Khan Academy
- Oak National Academy
- Seneca Learning
- Text book/guide
- Information/notes uploaded by your teacher(s) on your school's digital learning platform or other online platforms such as Google Classroom and Microsoft Teams
- Hwb Platform
- Information/notes in my class book/folder
- I did not use and/or make mind maps whilst accessing any of the learning resources mentioned above

3.a. Since the start of the COVID-19 pandemic until the present day, for any of the learning resources listed below have you **highlighted and/or underlined information/text** whilst accessing any of these learning resources for schoolwork, study and/or revision at home? Please tick all boxes that apply.

- BBC Bitesize
- Quizlet
- Tapio Cymru
- WJEC website
- AQA website
- Khan Academy
- Oak National Academy
- Seneca Learning
- Text book/guide
- Information/notes uploaded by your teacher(s) on your school's digital learning platform or other online platforms such as Google Classroom and Microsoft Teams
- Hwb Platform
- Information/notes in my class book/folder
- I did not highlight and/or underline information/text whilst accessing any of the learning resources mentioned above

3.b. Since the start of the COVID-19 pandemic until the present day, for any of the learning resources listed below have you used and/or made your own **flashcards** whilst accessing any of these learning resources for schoolwork, study and/or revision at home? Please tick all boxes that apply.

- BBC Bitesize
- Quizlet
- Tapio Cymru
- WJEC website
- AQA website
- Khan Academy
- Oak National Academy
- Seneca Learning
- Text book/guide
- Information/notes uploaded by your teacher(s) on your school's digital learning platform or other online platforms such as Google Classroom and Microsoft Teams
- Hwb Platform
- Information/notes in my class book/folder
- I did not use and/or make my own flashcards whilst accessing any of the learning resources mentioned above

3.c. Since the start of the COVID-19 pandemic until the present day, for any of the learning resources listed below have you **read information/notes over and over** whilst accessing any of these learning resources for schoolwork, study and/or revision at home? Please tick all boxes that apply.

- BBC Bitesize
- Quizlet
- Tapio Cymru
- WJEC website
- AQA website
- Khan Academy
- Oak National Academy
- Seneca Learning
- Text book/guide
- Information/notes uploaded by your teacher(s) on your school's digital learning platform or other online platforms such as Google Classroom and Microsoft Teams
- Hwb Platform
- Information/notes in my class book/folder
- I did not read information/notes over and over whilst accessing any of the learning resources mentioned above

3.d. Since the start of the COVID-19 pandemic until the present day, for any of the learning resources listed below have you made **notes** and/or **summarised information** whilst accessing any of these learning resources for schoolwork, study and/or revision at home? Please tick all boxes that apply.

- BBC Bitesize
- Quizlet
- Tapio Cymru
- WJEC website
- AQA website
- Khan Academy
- Oak National Academy
- Seneca Learning
- Text book/guide
- Information/notes uploaded by your teacher(s) on your school's digital learning platform or other online platforms such as Google Classroom and Microsoft Teams
- Hwb Platform
- Information/notes in my class book/folder
- I did not make notes and/or summarise information whilst accessing any of the learning resources mentioned above

3.e. Since the start of the COVID-19 pandemic until the present day, for any of the learning resources listed below have you used **spaced practice** whilst accessing any of these learning resources for schoolwork, study and/or revision at home? Please tick all boxes that apply. ***Spaced practice** involves spreading your study time and going over the same information.*

- BBC Bitesize
- Quizlet
- Tapio Cymru
- WJEC website
- AQA website
- Khan Academy
- Oak National Academy
- Seneca Learning
- Text book/guide
- Information/notes uploaded by your teacher(s) on your school's digital learning platform or other online platforms such as Google Classroom and Microsoft Teams

- Hwb Platform
- Information/notes in my class book/folder
- I did not use spaced practice whilst accessing any of the learning resources mentioned above

3.f. Since the start of the COVID-19 pandemic until the present day, for any of the learning resources listed below have you used **retrieval practice** whilst accessing any of these learning resources for schoolwork, study and/or revision at home? Please tick all boxes that apply. *Retrieval practice includes answering past paper questions, quizzes, being tested by someone else or any other activity which involves remembering information from memory without looking at the information that you are trying to remember*

- BBC Bitesize
- Quizlet
- Tapia Cymru
- WJEC website
- AQA website
- Khan Academy
- Oak National Academy
- Seneca Learning
- Text book/guide
- Information/notes uploaded by your teacher(s) on your school's digital learning platform or other online platforms such as Google Classroom and Microsoft Teams
- Hwb Platform
- Information/notes in my class book and/or folder
- I did not use retrieval practice whilst accessing any of the learning resources mentioned above

3.g. Since the start of the COVID-19 school pandemic until the present day, for any of the learning resources listed below have you used **interleaved practice (i.e., organising your study time so that you mix different kinds of problems or topics within a single study session)**, whilst accessing any of these learning resources for schoolwork, study and/or revision at home? Please tick all boxes that apply.

- BBC Bitesize
- Quizlet
- Tapia Cymru
- WJEC website
- AQA website
- Khan Academy
- Oak National Academy
- Seneca Learning
- Text book/guide
- Information/notes uploaded by your teacher(s) on your school's digital learning platform or other online platforms such as Google Classroom and Microsoft Teams
- Hwb Platform
- Information/notes in my class book/folder
- I did not use interleaved practice whilst accessing any of the learning resources mentioned above

3.h. Since the start of the COVID-19 pandemic until the present day, for any of the learning resources listed below have you used **elaborate encoding**, whilst accessing any of these learning resources for schoolwork, study and/or revision at home? Please tick all boxes that apply. *Elaborate encoding involves connecting what you are trying to learn to what you already know e.g. remembering the colours on the visible spectrum by learning the following sentence; Richard Of York Gave Battle In Vain [Red, Orange, Yellow, Green, Blue, Indigo and Violet]). These are called mnemonics.*

- BBC Bitesize
- Quizlet
- Tapia Cymru

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- WJEC website
- AQA website
- Khan Academy
- Oak National Academy
- Seneca Learning
- Text book/guide
- Information/notes uploaded by your teacher(s) on your school's digital learning platform or other online platforms such as Google Classroom and Microsoft Teams
- Hwb Platform
- Information/notes in my class book/folder
- I did not use elaborate encoding whilst accessing any of the learning resources mentioned above

The following questions ask you about how helpful you think the learning resources and strategies are for learning schoolwork, study and/or revision.

4. How effective (i.e., helpful) do you think the following learning strategies are for schoolwork, study and/or revision. Please tick the box that best describes your answer.

	Not at all helpful	Slightly helpful	Moderately helpful	Very helpful	Extremely helpful	I am not sure
Using mind maps	☐	☐	☐	☐	☐	☐
Highlighting or underlining information/text	☐	☐	☐	☐	☐	☐
Using flashcards	☐	☐	☐	☐	☐	☐
Reading information/notes over and over	☐	☐	☐	☐	☐	☐
Making notes and/or summarising information	☐	☐	☐	☐	☐	☐
Spaced practice (spreading your study time and going over the same information)	☐	☐	☐	☐	☐	☐
Retrieval practice (e.g., answering past paper questions, quizzes, being tested by someone or any other activity which involves remembering information from memory without looking at the information you are trying to remember).	☐	☐	☐	☐	☐	☐
Watching videos on the subject topic	☐	☐	☐	☐	☐	☐
Listening to audio on the subject topic	☐	☐	☐	☐	☐	☐
Interleaved practice (organising your study time so that you mix different kinds of problems or topics within a single study session)	☐	☐	☐	☐	☐	☐
Elaborate encoding (involves connecting what you are trying to learn to what you already know e.g., remembering the colours on the visible spectrum by learning the following sentence; Richard Of York Gave Battle in Vain [Red, Orange, Yellow, Green, Blue, Indigo and Violet])	☐	☐	☐	☐	☐	☐

5. How effective (i.e., helpful) do you think the following learning resources are for schoolwork, study and/or revision. Please tick the box that best describes your answer.

	Not at all helpful	Slightly helpful	Moderately helpful	Very helpful	Extremely helpful	I am not sure
BBC Bitesize	☐	☐	☐	☐	☐	☐
Quizlet	☐	☐	☐	☐	☐	☐
Tanio Cymru	☐	☐	☐	☐	☐	☐
Hwb Platform	☐	☐	☐	☐	☐	☐
WJEC website	☐	☐	☐	☐	☐	☐
AQA website	☐	☐	☐	☐	☐	☐
Khan Academy	☐	☐	☐	☐	☐	☐
Oak National Academy	☐	☐	☐	☐	☐	☐
Seneca Learning	☐	☐	☐	☐	☐	☐
Text book/guide	☐	☐	☐	☐	☐	☐
Information/notes uploaded by your teacher(s) on your school's digital learning platform or other online platforms such as Google Classroom and Microsoft Teams	☐	☐	☐	☐	☐	☐

Information/notes in my class book and/or folder	☐	☐	☐	☐	☐	☐

Before the school closures caused by the COVID-19 pandemic, learners were in schools following their usual school timetables. We understand that learning schoolwork and studying at home during the COVID-19 school closures was very different.

The following questions ask you about the time that you might have spent on schoolwork and/or study during the COVID-19 school closures.

6. During the COVID-19 pandemic think about a week when you were learning at home all the time and did not go to school. For that week, how many hours of schoolwork did you do at home. Please tick ONE box. *Schoolwork is any work that your teacher asked you to do and given to you by your teacher(s) (i.e., classwork, online classroom lessons with your teacher(s)).*

- None
- Less than 1 hour a week
- 1-2 hours a week
- 2-3 hours a week
- 3-4 hours a week
- 4-5 hours a week
- 5-6 hours a week
- 6-7 hours a week
- More than 7 hours a week

6.a. During the COVID-19 pandemic think about a week when you were learning at home. How many hours of independent study did you do at home when your school was closed. Please tick ONE box. *Independent study can be spending some time going over the schoolwork that you have learned by yourself, or any additional work that you set yourself to do.*

- None
- Less than 1 hour a week
- 1-2 hours a week
- 2-3 hours a week
- 3-4 hours a week
- 4-5 hours a week
- 5-6 hours a week
- 6-7 hours a week
- More than 7 hours a week

This section of the survey asks you about your experiences of using digital learning platforms and other online learning platforms such as Google Classroom and Microsoft Teams since the start of the COVID-19 school closures until the present day.

Your answers will help us to understand what we need to do to support pupils with using digital learning platforms. Your answers will also help us to make sure schools know about the support pupils need with using online learning platforms.

7. At the start of the COVID-19 school closures when you started home learning, how confident did you feel about using the following digital learning platforms? Please tick the box that best describes your answer.

	Not confident at all	Slightly confident	Somewhat confident	Very confident	Extremely confident	Our school did not use this / We did not use this
Hwb Platform	☐	☐	☐	☐	☐	☐
Microsoft Teams	☐	☐	☐	☐	☐	☐
Google classroom	☐	☐	☐	☐	☐	☐
Moodle	☐	☐	☐	☐	☐	☐
Show my homework	☐	☐	☐	☐	☐	☐

7.a. How confident do you NOW feel about using the following digital learning platforms. Please tick the box that best describes your answer.

	Not confident at all	Slightly confident	Somewhat confident	Very confident	Extremely confident	Our school did not use this / We did not use this
Hwb Platform	☐	☐	☐	☐	☐	☐
Microsoft Teams	☐	☐	☐	☐	☐	☐
Google classroom	☐	☐	☐	☐	☐	☐
Moodle	☐	☐	☐	☐	☐	☐
Show my homework	☐	☐	☐	☐	☐	☐

7.b. If you used a different digital learning platform to communicate with your ~~school teacher~~(s) during the school closures that is not mentioned above, please write this information in the space below and please tick ONE box to show how confident you felt about using that learning platform.

		How confident did you feel about using this digital learning platform? Please tick ONE option alongside each box you write in.					How confident do you NOW this digital learning platform. Ple alongside each box yo		
	Please write your answer(s) in the space below.	Not confident at all	Slightly confident	Somewhat confident	Very confident	Extremely confident	Not confident at all	Slightly confident	Somewhat confident
Please write one answer in each box		☐	☐	☐	☐	☐	☐	☐	☐
Please write one answer in each box		☐	☐	☐	☐	☐	☐	☐	☐

Please write one answer in each box		☐	☐	☐	☐	☐	☐	☐	☐
Please write one answer in each box		☐	☐	☐	☐	☐	☐	☐	☐
Please write one answer in each box		☐	☐	☐	☐	☐	☐	☐	☐

8. At the **start of the COVID-19 school closures**, how confident did you feel about each of the following aspects of learning? Please tick the box that best describes your answer.

	Not confident at all	Slightly confident	Somewhat confident	Very confident	Extremely confident
Learning schoolwork on my own outside of school without help from ~~school teacher~~(s)	☐	☐	☐	☐	☐
Using online learning resources	☐	☐	☐	☐	☐
Using the internet for finding effective (i.e., helpful) learning resources	☐	☐	☐	☐	☐
Using effective (i.e., evidence-informed) learning strategies	☐	☐	☐	☐	☐
Using the internet for finding effective (i.e., helpful) learning strategies	☐	☐	☐	☐	☐
Using offline learning resources (e.g., textbooks, study/revision guides)	☐	☐	☐	☐	☐
Studying on my own outside of school (i.e., doing work other than homework)	☐	☐	☐	☐	☐
Revising on my own in preparation for class tests, external exams at home	☐	☐	☐	☐	☐

8.a How confident do you **NOW** feel about each of the following aspects of learning? Please tick the box that best describes your answer.

	Not confident at all	Slightly confident	Somewhat confident	Very confident	Extremely confident
Learning schoolwork on my own outside of school without help from ~~school teacher~~(s)	☐	☐	☐	☐	☐
Using online learning resources	☐	☐	☐	☐	☐

Using the internet for finding effective (i.e., helpful) learning resources	☐	☐	☐	☐	☐
Using effective (i.e., evidence-informed) learning strategies	☐	☐	☐	☐	☐
Using the internet for finding effective (i.e., helpful) learning strategies	☐	☐	☐	☐	☐
Using offline learning resources (e.g., textbooks, study/revision guides)	☐	☐	☐	☐	☐
Studying on my own outside of school (i.e., doing work other than homework)	☐	☐	☐	☐	☐
Revising on my own in preparation for class tests, external exams at home	☐	☐	☐	☐	☐

The following questions ask you about the learning strategies mentioned in the questions above. To see the strategies again click on More Info.

9. If you know about any of these **learning strategies**, please tell us where you found out about them? Please tick all boxes that apply.

More info

- ☐ School teacher(s)
- ☐ School study/revision tutor
- ☐ School study/revision support centre
- ☐ Parents/carers
- ☐ Friend(s)/peers
- ☐ Online (e.g., learning resources, social media)
- ☐ Private tutor(s)

9.a. If there are any other people or place(s) where you have learned about **learning strategies**, please write this in the space below.

The following questions ask you about the learning resources mentioned in the questions above. To see the resources again click on More Info.

10. If you know about any of these online/offline **learning resources**, please tell us where you found out about them? Please tick all boxes that apply.

More info

- ☐ School teacher(s)
- ☐ School study/revision tutor(s)
- ☐ School study/revision support Centre
- ☐ Parents/carers
- ☐ Friend(s)/peers
- ☐ Online (e.g., learning resources, social media)
- ☐ Private tutor(s)

10.a. If there are any other people or place(s) where you have learned about **learning resources**, please write this in the space below.

The following survey questions are about learning at school.

11. Imagine that you are planning to study and/or revise for some information that you have learned in school. Please tick the option that best describes why you might use **retrieval practice** to study/revise the information that you have learned in school. ***Retrieval practice*** *includes answering past paper questions, quizzes, being tested by someone else or any other activity which involves remembering information from memory without looking at the information that you are trying to remember.* Please only tick **ONE** option.

- Using retrieval practice when I study/revise will help me to know how well I have learned the information.
- Using retrieval practice when I study/revise will help me to learn and remember the information.
- I do not think using retrieval practice when I study/revise will help me learn and remember the information.

12. Imagine that you are planning to study and/or revise for some information that you have learned in school. Please tick the option that best describes why you might **space out (i.e., spread out)** your study/revision sessions. Please only tick **ONE** option.

- Spacing out my study/revision sessions over multiple days/weeks will help me to learn more information.
- Spacing out my study/revision sessions over multiple days/weeks will help me to learn and remember the information.
- I do not think spacing out my study/revision sessions over multiple days/weeks will help me to learn and remember the information.

13. Which of the following strategies do you think research has found to be better for long-term retention of material (i.e., for remembering information), assuming the total amount of study is the same? Please only tick ONE option

- Studying the material in multiple sessions of shorter duration
- Studying the material in one longer session
- Both strategies are equally effective (i.e., helpful).

14. Imagine that you are planning to study and/or revise for some information that you have learned in school. Please tick the option that best describes why you might **use flashcards** to study/revise the information that you have learned in school. Please only tick **ONE** option.

- Using flashcards when I study/revise will help me to learn because it allows me to read the information over and over.
- Using flashcards when I study/revise will help me to learn because it allows me to practise bringing the answer to my mind.
- Using flashcards when I study/revise will help me to learn because it helps to break up the information into smaller amounts to practise.
- I do not think using flashcards when I study/revise will help me to learn the information.

15. Imagine that you are planning to study and/or revise for some information that you have learned in school. Please tick the option that best describes why you might use **mind maps** when you study/revise the information that you have learned. Please only tick **ONE** option.

- Using mind maps when I study/revise will help me to learn because it allows me to read the information over and over.
- Using mind maps when I study/revise will help me to learn because it allows me to practise bringing the information to my mind.
- Using mind maps when I study/revise will help me to identify the main topic and link this to related topics, with words that make sense to me.
- I do not think using mind maps when I study/revise will help me to learn the information.

This is the final section of the survey.

The following questions ask you about the support for pupils with schoolwork, study and/or revision during the COVID-19 school closures until the present day.

16. During the COVID-19 school closures, how helpful was the support you received from your school for the following aspects of home learning. Please tick the box that best describes your answer.

	Not at all helpful	Somewhat helpful	Moderately helpful	Very helpful	Extremely helpful
Using your school's digital learning platform	☐	☐	☐	☐	☐
Using other online platforms such as Google Classroom, Microsoft Teams to access schoolwork and/or communicate with your school teacher(s)	☐	☐	☐	☐	☐

17. Is there anything else that you find particularly helpful that you used to learn schoolwork, study and/or revise at home? This can be things in addition to online/offline learning resources. Please write your answer in the space below.

18. Do you think that you should be provided with information about effective learning strategies and/or learning resources to help you with schoolwork, study/revision in the event of any future school closures? Please tick the box.

- Yes
- No

19. Would you be interested in receiving information about effective (i.e., evidence-informed) learning strategies and/or learning resources that will help you to learn schoolwork, study/revise effectively? Please tick the box.

- Yes
- No

20. What year group are you in? Please tick the box.

- Year 10
- Year 12

Appendix S. Frequency outcomes for survey items (Appendix E)

Table S. 1 *Weighted percentage scores for learner responses to the survey questions, "At the start of the COVID-19 school closures, how confident did you feel about each of the following aspects of learning" and, "How confident do you now feel about each of the following aspects of learning"?*

Study skill	**Not confident at all**	**Slightly confident**	**Somewhat confident**	**Very confident**	**Extremely confident**
	% (SE)	***% (SE)***	***% (SE)***	***% (SE)***	***% (SE)***
Learning schoolwork on my own outside of school without help from school teacher(s) **Before**	21.1 (5.1)	25.7 (5.2)	30.1 (5.6)	16.1(4.3)	7.1 (3.1)
Learning schoolwork on my own outside of school without help from school teacher(s) **Now**	5.8 (2.9)	13.5 (4.0)	31.4 (5.7)	34.0 (5.8)	15.4 (4.4)
Using online learning resources **Before**	13.4 (4.3)	15.4 (4.4)	39.2 (5.9)	26.9 (5.5)	5.1 (2.5)
Using online learning resources **Now**	7.1 (3.1)	8.3 (3.3)	23.7 (5.1)	37.2 (5.9)	23.7(5.1)
Using the internet for finding effective (i.e., helpful) learning resources	9.7 (3.8)	21.4 (5.0)	37.1 (5.8)	19.4 (4.9)	12.4 (3.9)

Study skill	**Not confident at all**	**Slightly confident**	**Somewhat confident**	**Very confident**	**Extremely confident**
	% (SE)	***% (SE)***	***% (SE)***	***% (SE)***	***% (SE)***
Before					
Using the internet for finding effective (i.e., helpful) learning resources **Now**	9.0 (3.6)	6.4 (2.8)	33.4 (5.7)	34.0 (5.8)	17.3 (4.6)
Using effective (i.e., evidence-informed) learning strategies **Before**	23.7 (5.3)	25.0 (5.3)	30.8 (5.5)	12.2 (3.9)	8.3 (3.3)
Using effective (i.e., evidence-informed) learning strategies **Now**	7.7 (3.4)	21.8 (5.1)	25.7 (5.2)	25.0 (5.2)	19.9 (4.9)
Using the internet for finding effective (i.e., helpful) learning strategies **Before**	19.8 (5.0)	18.0 (4.6)	35.9 (5.8)	19.3 (4.7)	7.1 (3.1)
Using the internet for finding effective (i.e., helpful) learning strategies **Now**	9.8 (3.9)	9.9 (3.6)	29.0 (5.5)	32.2 (5.8)	19.1 (4.9)

Study skill	Not confident at all	Slightly confident	Somewhat confident	Very confident	Extremely confident
	% (SE)	*% (SE)*	*% (SE)*	*% (SE)*	*% (SE)*
Using offline learning resources (e.g., textbooks, study/revision guides) **Before**	16.9 (4.7)	17.0 (4.6)	29.5 (5.4)	26.8 (5.5)	9.8 (3.6)
Using offline learning resources (e.g., textbooks, study/revision guides) **Now**	9.6 (3.8)	9.0 (3.3)	23.7 (5.1)	35.3 (5.8)	22.4 (5.1)
Studying on my own outside of school (i.e., doing work other than homework) **Before**	21.1 (5.1)	26.3 (5.3)	17.3 (4.5)	23.7 (5.1)	11.5 (3.9)
Studying on my own outside of school (i.e., doing work other than homework) **Now**	8.3 (3.3)	12.2 (3.9)	26.9 (5.4)	32.0 (5.7)	20.5 (4.8)
Revising on my own in preparation for class tests, external exams at home **Before**	20.5 (5.0)	19.9 (4.9)	30.2 (5.5)	19.9 (4.9)	9.6 (3.5)

Study skill	**Not confident at all**	**Slightly confident**	**Somewhat confident**	**Very confident**	**Extremely confident**
	% (SE)	***% (SE)***	***% (SE)***	***% (SE)***	***% (SE)***
Revising on my own in preparation for class tests, external exams at home **Now**	9.6 (3.5)	10.3 (3.5)	25.0 (5.3)	34.0 (5.8)	21.2 (5.0)

Table S. 2 *Weighted percentage scores for learner responses to the survey question, "During the COVID-19 school closures, how helpful was the support you received from your school for the following aspects of home learning"?*

Learning activity	**Not at all helpful**	**Somewhat helpful**	**Moderately helpful**	**Very helpful**	**Extremely helpful**
	% (SE)	***% (SE)***	***% (SE)***	***% (SE)***	***% (SE)***
Using your school's digital learning platform	12.9 (4.3)	23.8 (5.3)	40.8 (6.1)	15.7(4.4)	6.8 (3.0)
Using other online platforms such as Google Classroom, Microsoft teams to access schoolwork and/or communicate with your school teacher(s)	4.1 (2.3)	18.4 (4.7)	36.1 (5.9)	21.7(5.4)	19.7 (5.0)